FIG. 1(a)

```
      ┌──────────────┐
     ╱  SENSE        ╱
    ╱   PHYSICAL    ╱──── 100
   ╱    ACTIVITY   ╱
  └──────────────┘
         │
         ▼
  ┌──────────────┐
  │     A/D      │──── 105
  │  CONVERSION  │
  └──────────────┘
         │
         ▼
  ┌──────────────┐
  │   SMOOTH     │
  │ DIGITAL SIGNAL│──── 110
  │  (OPTIONAL)  │
  └──────────────┘
         │
         ▼
  ┌──────────────────┐      ┌──────────┐      ┌──────────┐
  │ SIFT SIGNAL WITH │─ 120 │ DISPLAY  │      │  CHECK   │
  │ EMPIRICAL MODE   │      │INTRINSIC MODE│  │ORTHOGONALITY│
  │ DECOMPOSITION METHOD│──▶│ FUNCTIONS │      │          │
  │ TO EXTRACT INTRINSIC│   └──────────┘      └──────────┘
  │ MODE FUNCTIONS   │         130                135
  └──────────────────┘
         │
         ▼
  ┌──────────────────────┐
  │ APPLY HILBERT TRANSFORM│
  │ TO INTRINSIC MODE FUNCTIONS│──── 140
  │ TO GENERATE HILBERT SPECTRUM│
  └──────────────────────┘
```

- 150 CALCULATE INSTANTANEOUS ENERGY DENSITY
- 155 SMOOTH HILBERT SPECTRUM (OPTIONAL)
- 160 CALCULATE INSTANTANEOUS FREQUENCY
- 145 CALCULATE MARGINAL HILBERT SPECTRUM
- 165 CALCULATE STATIONARITY MEASUREMENTS

DISPLAY RESULTS OF SELECTED CALCULATIONS —— 190

END —— 195

FIG. 1(b)

```
┌─────────────┐      ┌──────────┐      ┌──────────┐
│ DIGITIZED   │      │  FROM    │      │   FROM   │
│ PHYSICAL    │      │ STEP 265 │      │ STEP 320 │
│ SIGNAL      │      └────┬─────┘      └────┬─────┘
│ FROM STEP 105│          │                 │
└──────┬──────┘           │                 │
       │                  │                 │
       ▼                  │                 │
  ┌─────────────┐◄────────┘                 │
107│  FRAME      │◄──────────────────────────┘
   │  END POINTS │
   └──────┬──────┘
          │
          ▼
   ┌─────────────┐
200│ IDENTIFY LOCAL│
   │ MAXIMA POINTS │
   │ OF PHYSICAL   │
   │ SIGNAL        │
   └──────┬──────┘
          │
          ▼
       ╱─────────╲                    ┌──────────────────┐
201   ╱ INTERMITTENCY╲      YES        │ TREAT MAXIMA FAILING│
      ╲ TEST MAXIMA? ╱─────────────────►│ INTERMITTENCY TEST │
       ╲─────────╱                     │ AS LOCAL MINIMA    │
          │ NO                         └────────┬─────────┘
          │                                     │     202
          ▼                                     │
   ┌─────────────┐◄──────────────────────────────┘
210│ CONSTRUCT     │
   │ UPPER ENVELOPE│
   │ OF PHYSICAL   │
   │ SIGNAL        │
   └──────┬──────┘
          │
          ▼
   ┌─────────────┐
220│ IDENTIFY LOCAL│
   │ MINIMA POINTS │
   │ OF PHYSICAL   │
   │ SIGNAL        │
   └──────┬──────┘
          │
          ▼
       ╱─────────╲                    ┌──────────────────┐
221   ╱ INTERMITTENCY╲      YES        │ TREAT MINIMA FAILING│
      ╲ TEST MINIMA? ╱─────────────────►│ INTERMITTENCY TEST │
       ╲─────────╱                     │ AS LOCAL MAXIMA    │
          │ NO                         └────────┬─────────┘
          │                                     │     222
          ▼                                     │
   ┌─────────────┐◄──────────────────────────────┘
230│ CONSTRUCT     │
   │ LOWER ENVELOPE│
   │ OF PHYSICAL   │
   │ SIGNAL        │
   └──────┬──────┘
          │
          ▼
   ┌─────────────┐
240│ DETERMINE     │
   │ ENVELOPE MEAN │
   │ OF PHYSICAL   │
   │ SIGNAL        │
   └──────┬──────┘
          │
          ▼
   ┌─────────────┐
   │    TO       │
   │  STEP 250   │
   └─────────────┘
```

FIG. 1(c)

```
        ┌──────────────┐
        │     FROM     │
        │   STEP 240   │
        └──────┬───────┘
               ↓
┌──────────────────────────────────┐
│ GENERATE COMPONENT SIGNAL        │
│ BY SUBTRACTING ENVELOPE          │    250
│ MEAN FORM PHYSICAL SIGNAL        │
└──────────────┬───────────────────┘
               ↓
```

250 — GENERATE COMPONENT SIGNAL BY SUBTRACTING ENVELOPE MEAN FORM PHYSICAL SIGNAL

260 — HAS STOPPING CRITERIA BEEN SATISFIED ?

NO — 265 — TREAT THE COMPONENT AS PHYSICAL SIGNAL DURING NEXT ITERATION

TO STEP 200

YES

STORAGE

275

270 — COMPONENT SIGNAL IS AN INTRINSIC MODE FUNCTION (IMF)

MEMORY 415

290 — GENERATE RESIDUAL SIGNAL BY SUBTRACTING THE IMF FROM PHYSICAL SIGNAL

310 — STOP

300 — CHECK IF THERE ARE MORE THAN 2 EXTREMA

NO

320 — TREAT THE RESIDUAL SIGNAL AS THE PHYSICAL SIGNAL DURING NEXT ITERATION

YES

SENSE
PHYSICAL PHENOMENON
OR
INPUT PHYSICAL SIGNAL ⟋⟍100

SMOOTH SIGNAL
(OPTIONAL) ⟋105

DISPLAY ⟋130

120

SIFT SIGNAL WITH
EMPIRICAL MODE DECOPOSITION
TO EXTRACT IMF'S

STORE ⟋132

TRANSMIT
134

370

CALCULATE
OSCILLATORY
ENERGY ABOUT
THE MEAN

CONSTRUCT FILTERED SIGNAL
FROM A SUBSET OF IMF'S ⟋350

FIT A CURVE TO
THE FILTERED SIGNAL ⟋360

OUTPUT
CURVE
FUNCTION

DISPLAY
CURVE

STORE
CURVE

TRANSMIT
CURVE

362   364   366   368

FIG. 1(d)

FIG. 2

400

430 — KEYBOARD

435 — MOUSE

440 — INPUT DEVICE

442 — SENSOR

444 — SENSOR

COMPUTER — 410

MEMORY — 415

480 — DISC

420 — MASS STORAGE DEVICE

450 — DISPLAY

460 — PRINTER

470 — OUTPUT DEVICE

FIG. 3(a)

FIG. 3(b)

FIG. 3(c)

First Component Signal (h_1)

FIG. 3(d)

Second Component Signal (h_{11})

FIG. 3(e)

Third Component Signal (h_{12})

FIG. 3(f)

First IMF Component

FIG. 3(g)

Data with Intermittency

EMD-IMF without intermittency option

FIG. 3(h)

c1

FIG. 3(i)

c2

FIG. 3(j)

c3

FIG. 3(k)

EMD-IMF without intermittency option

c1

FIG. 3(l)

c2

FIG. 3(m)

c3

FIG. 4(a)

Wind Data graph: Wind Speed (m/sec) versus Time (sec)
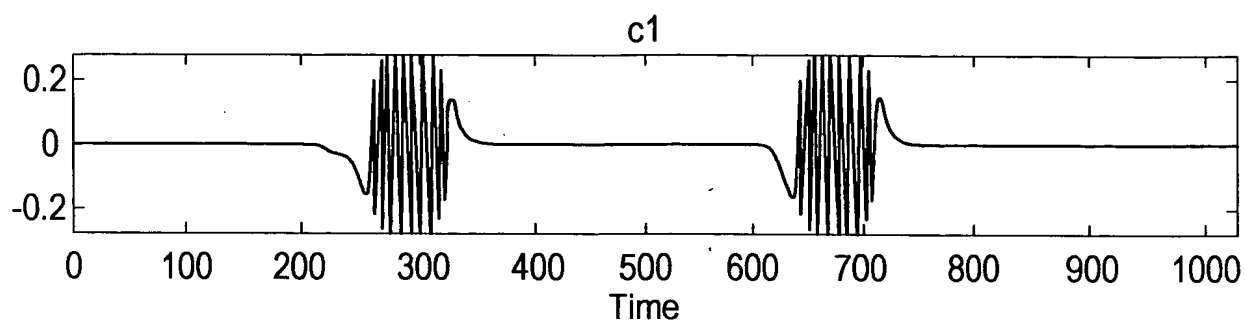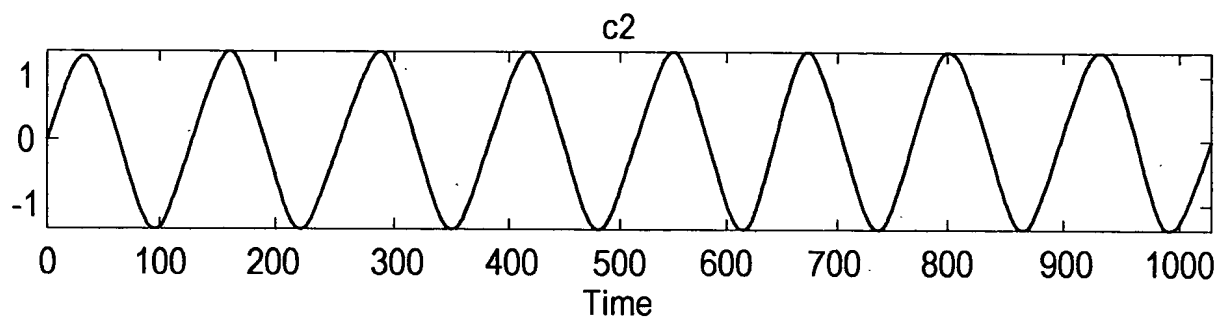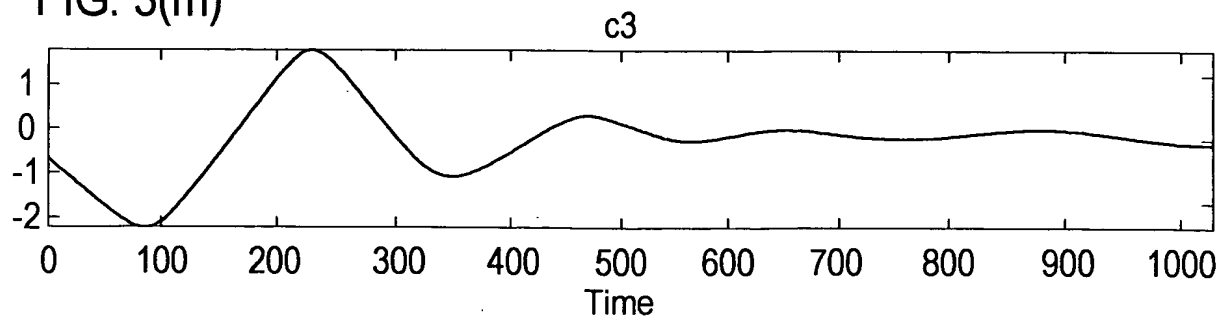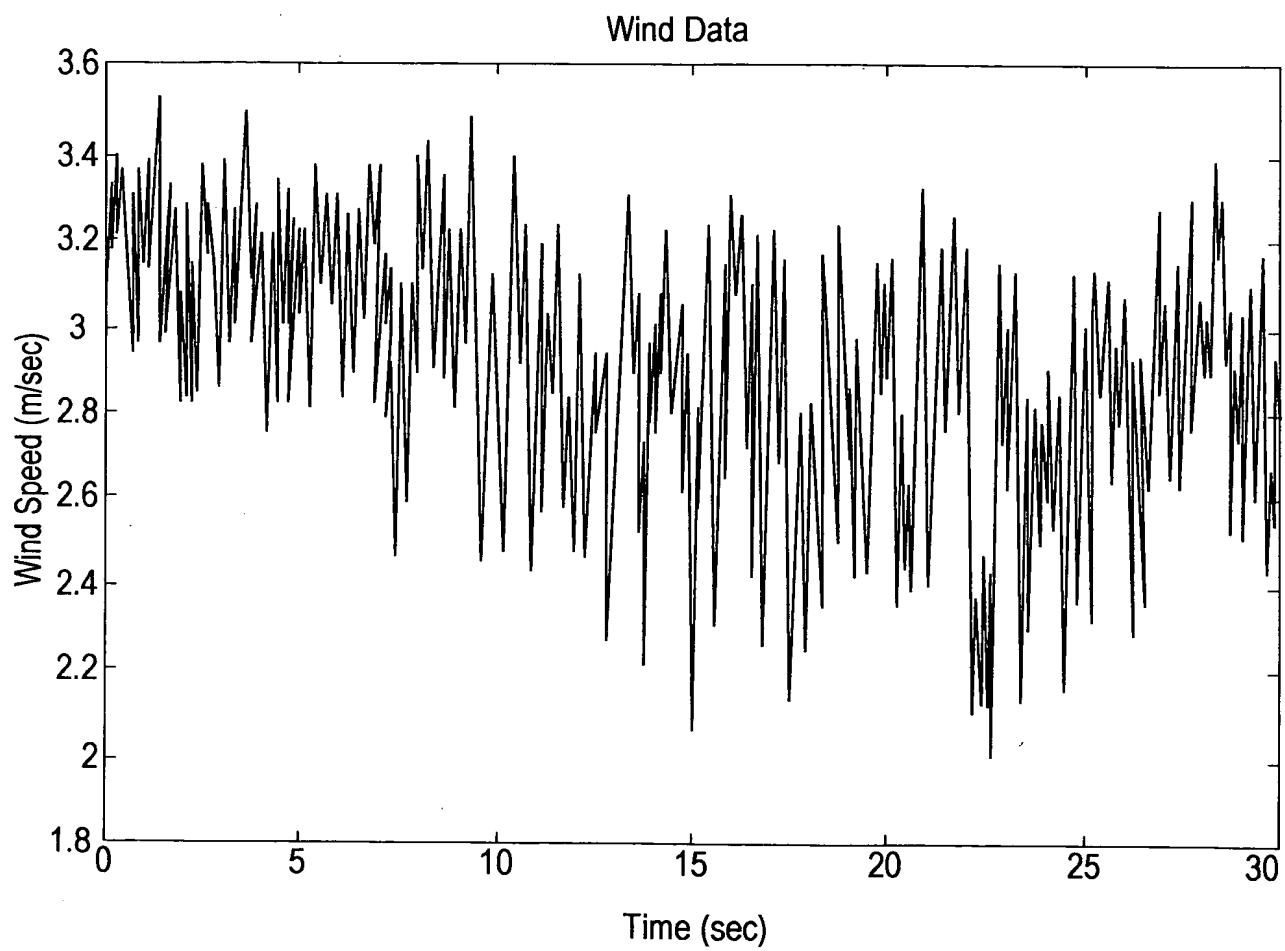
FIG. 4(b)
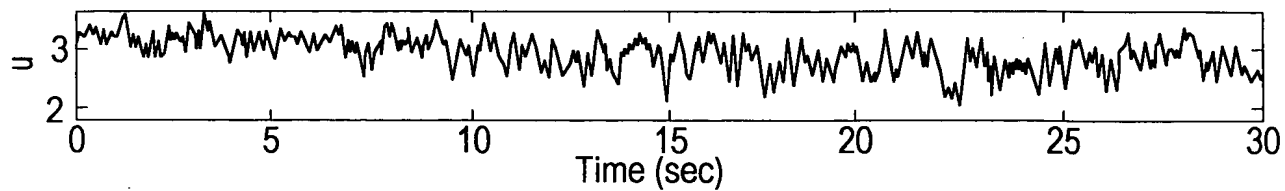
FIG. 4(c)
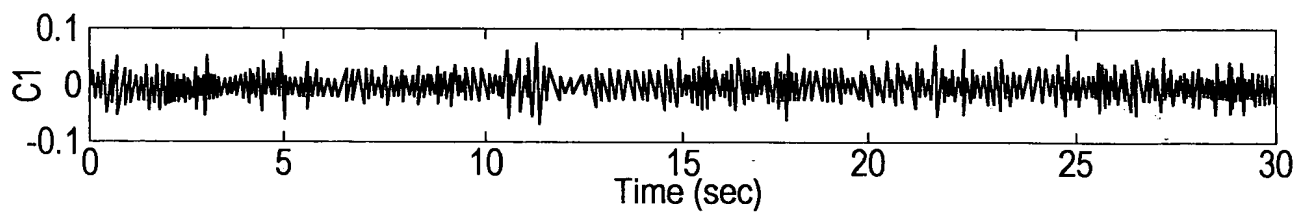
FIG. 4(d)
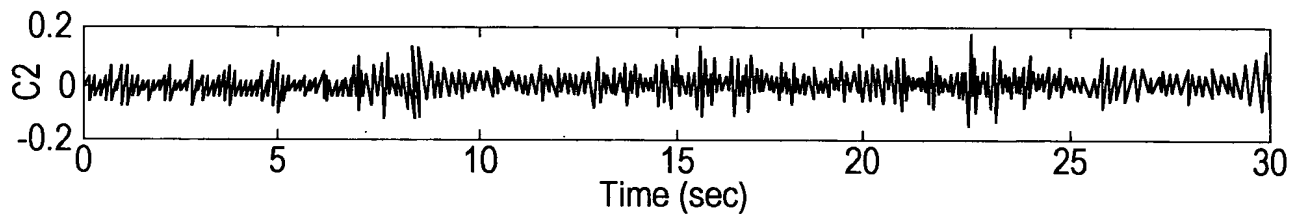
FIG. 4(e)
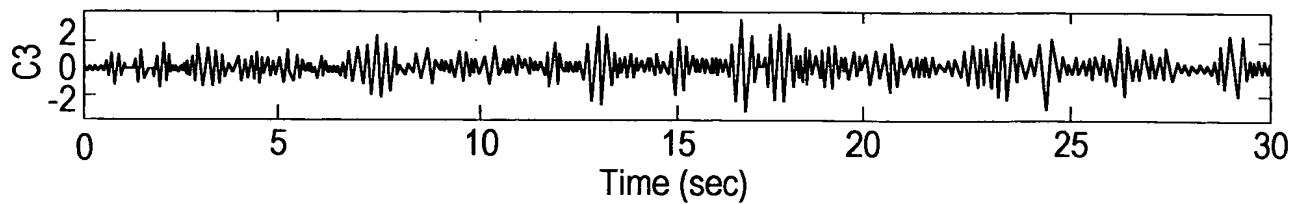
FIG. 4(f)
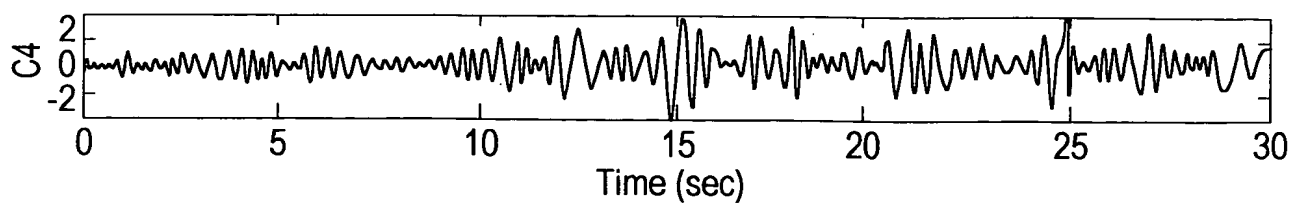
FIG. 4(g)
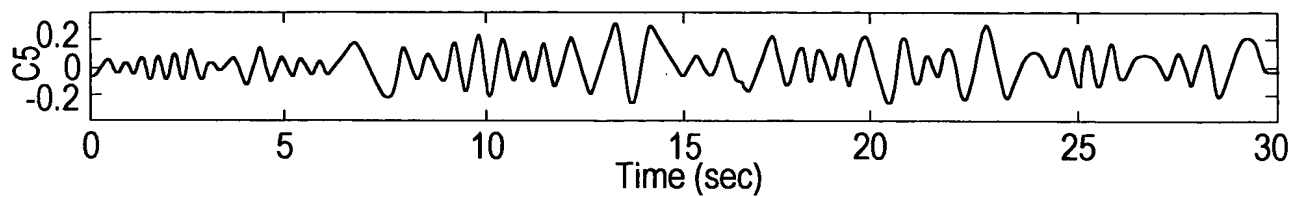
FIG. 4(h)
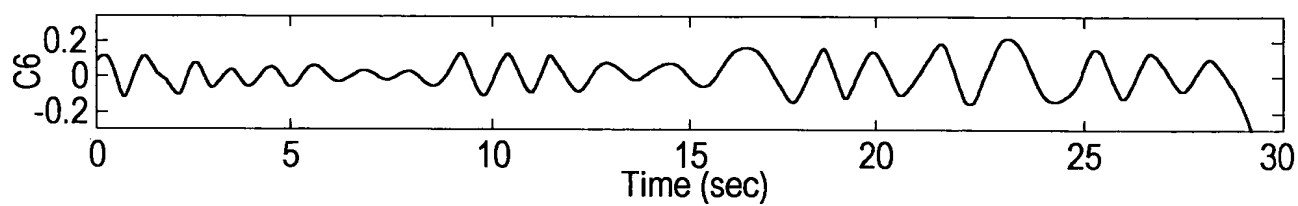
FIG. 4(i)
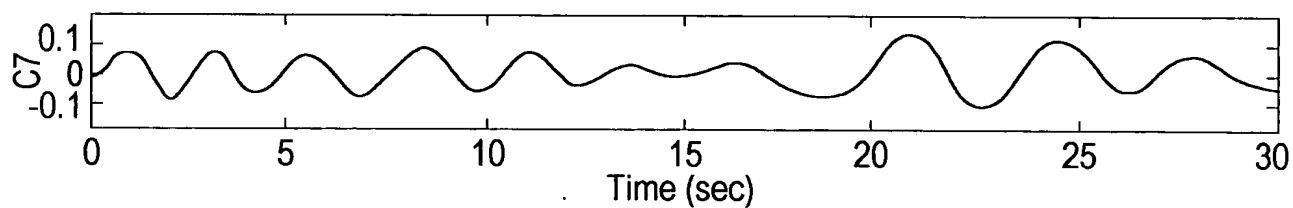
FIG. 4(j)
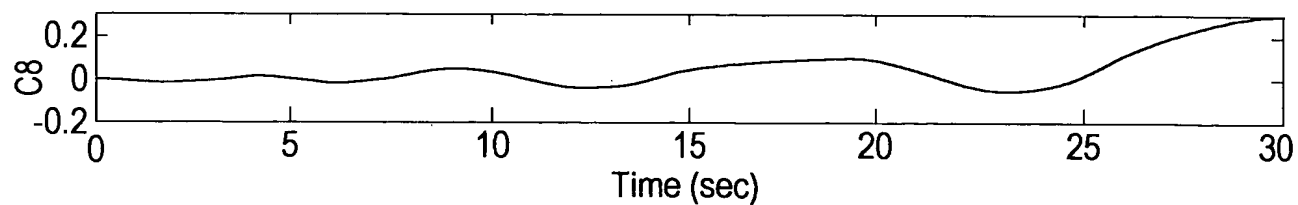
FIG. 4(k)
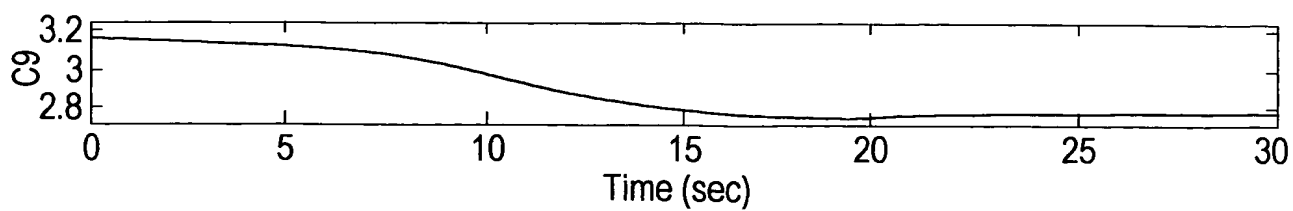
FIG. 5(a)
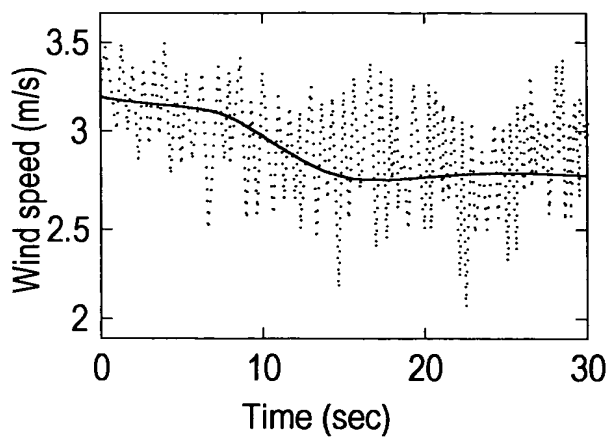
FIG. 5(b)
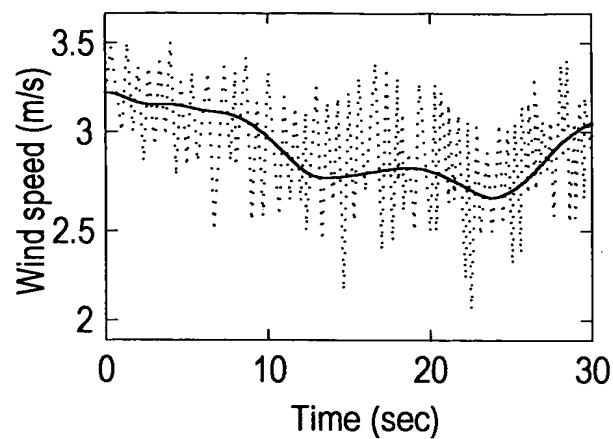
FIG. 5(c)
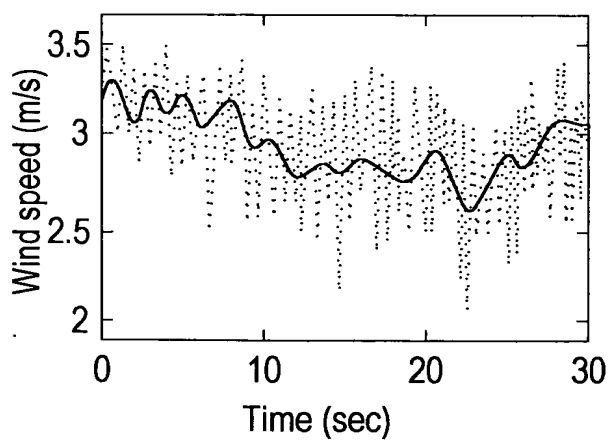
FIG. 5(d)
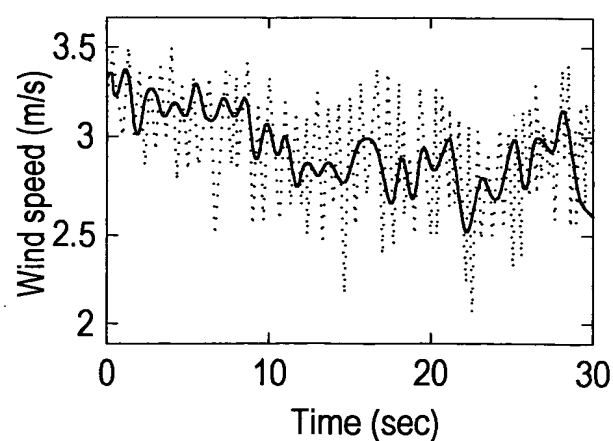
FIG. 5(e)
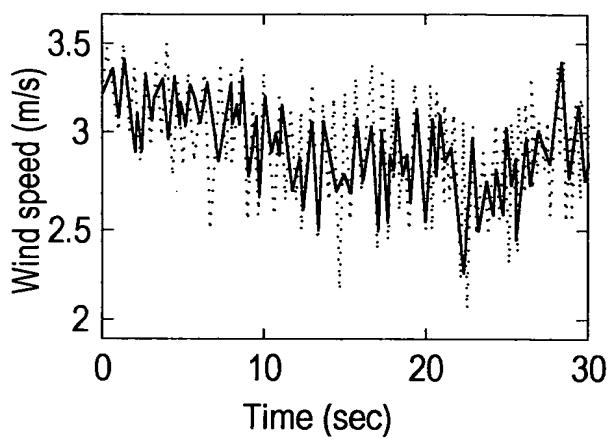
FIG. 5(f)
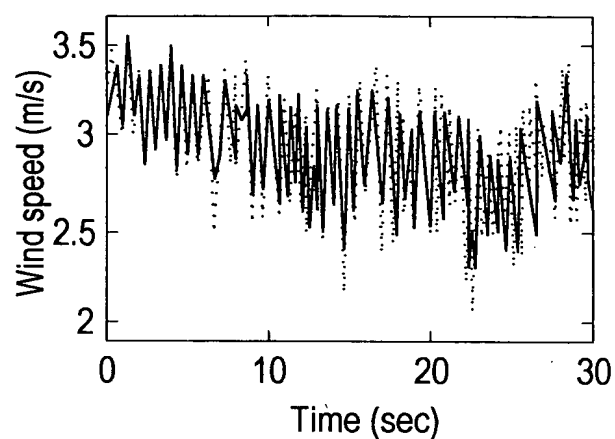
FIG. 5(g)

FIG. 5(h)

FIG. 5(i)
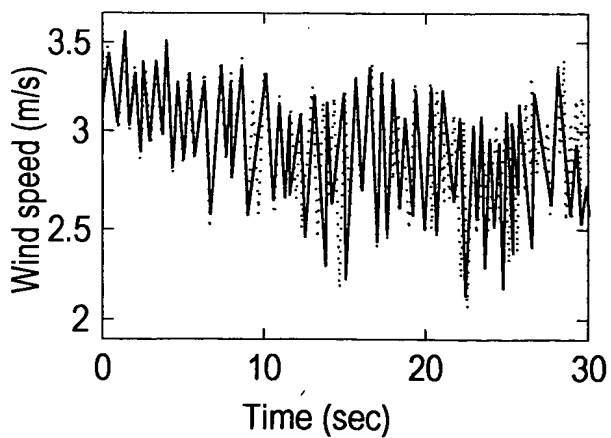
FIG. 5(j)
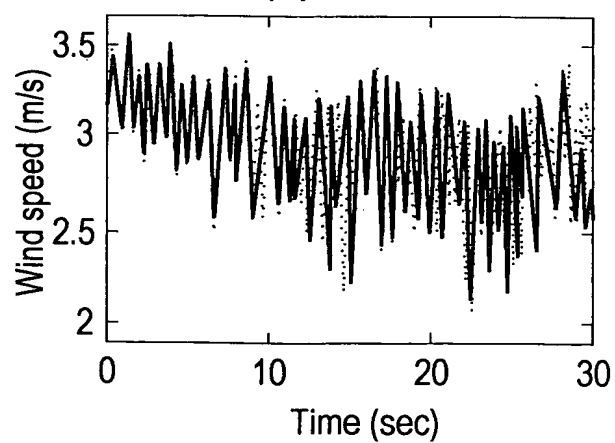
FIG. 6(a)
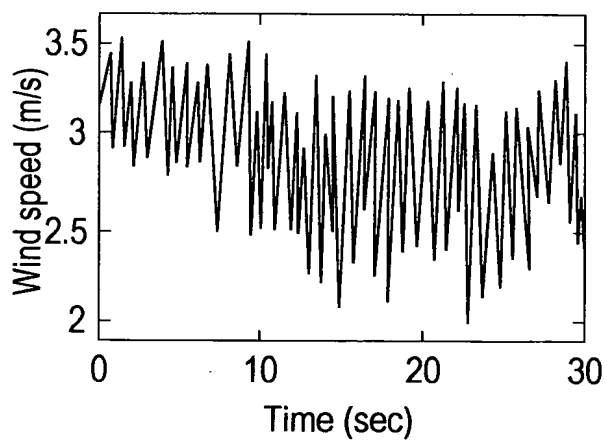
Hilbert Spectrum for Laboratory Wind Data
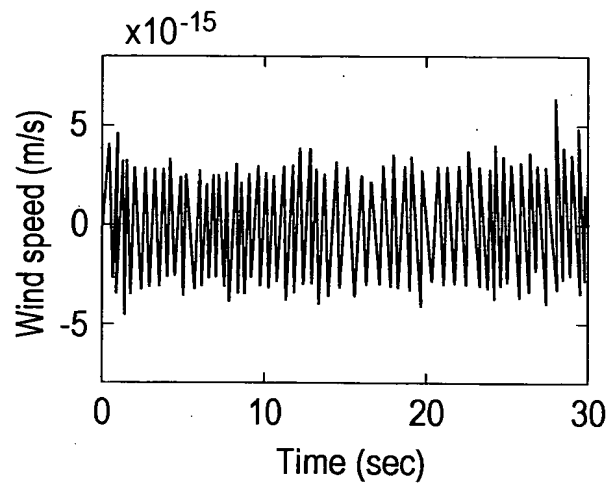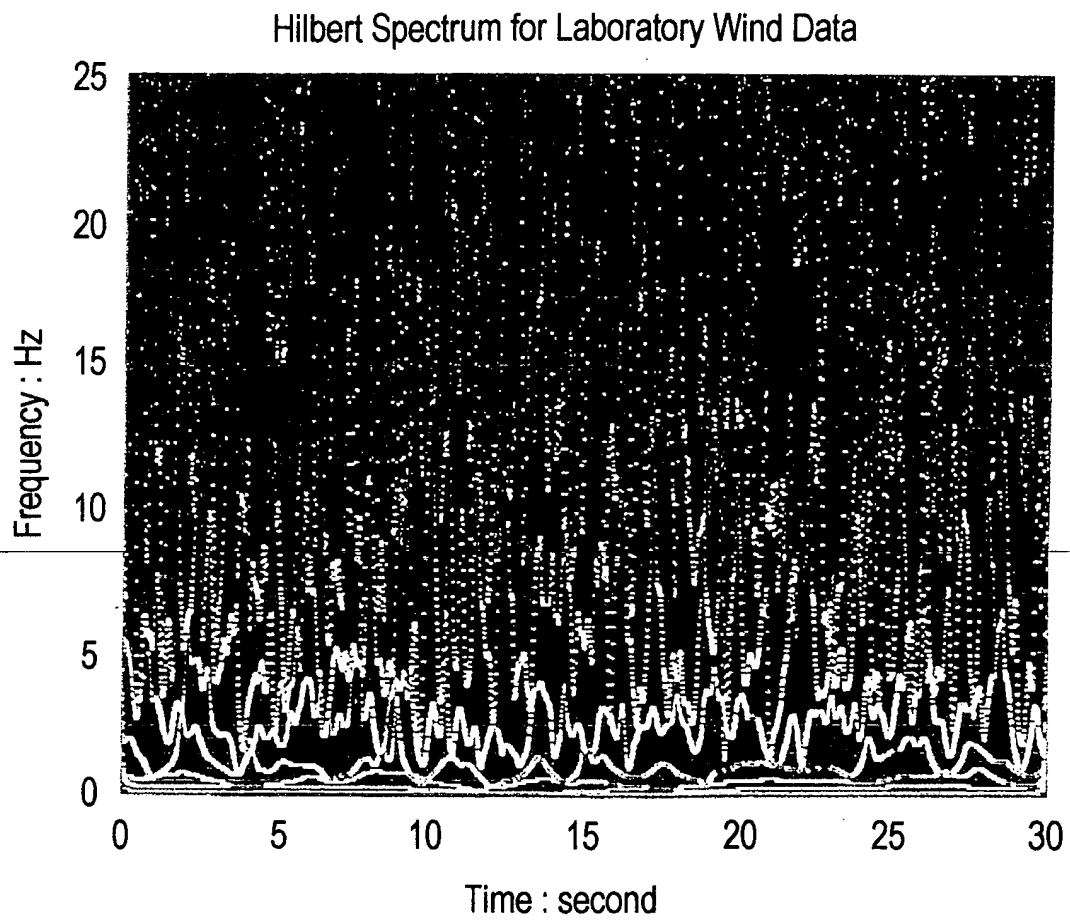
FIG. 6(b)

Wavelet Spectrum for Laboratory Wind Data
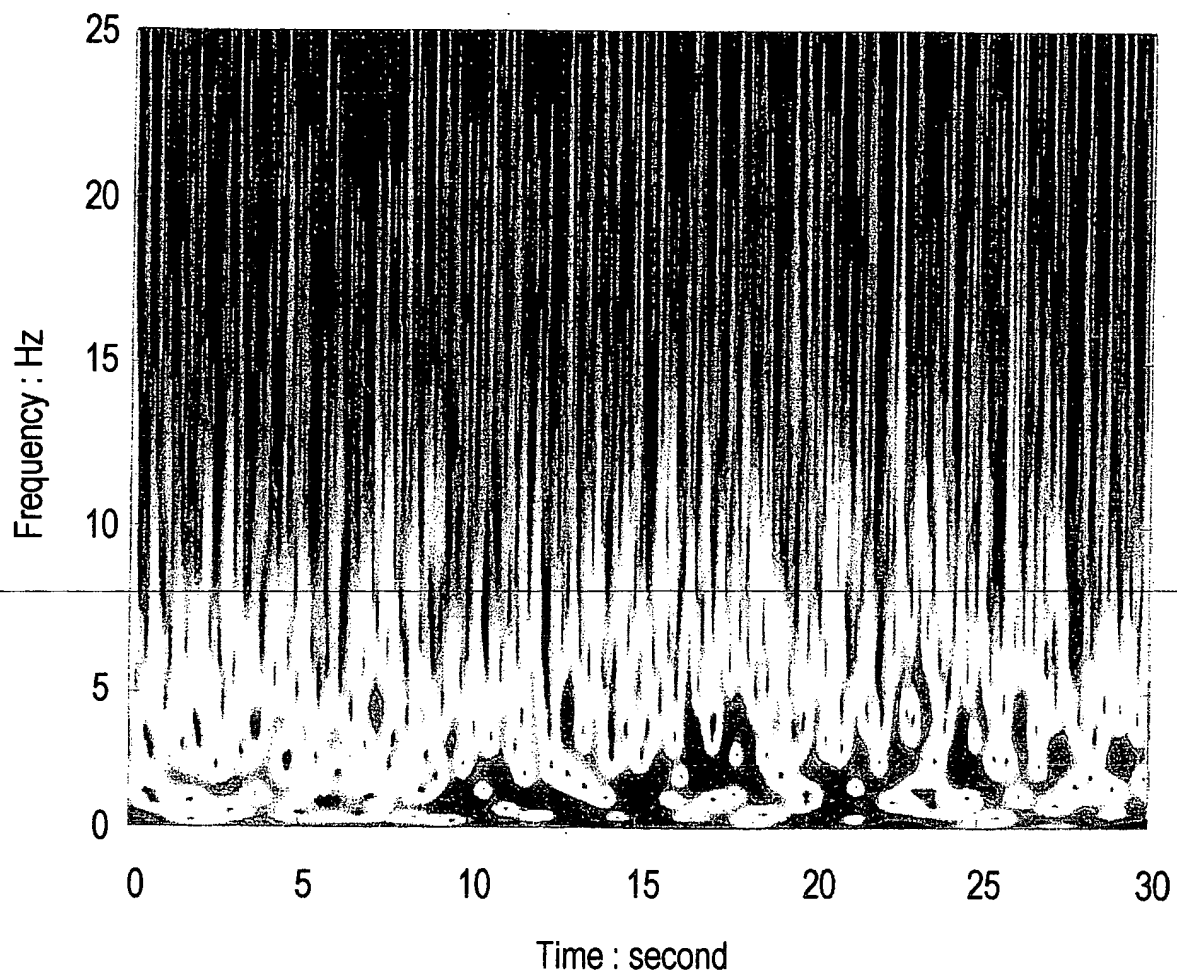
FIG. 6(c)

Hilbert Spectrum for Laboratory Wind Data : 15x15 Smoothed

Time : second
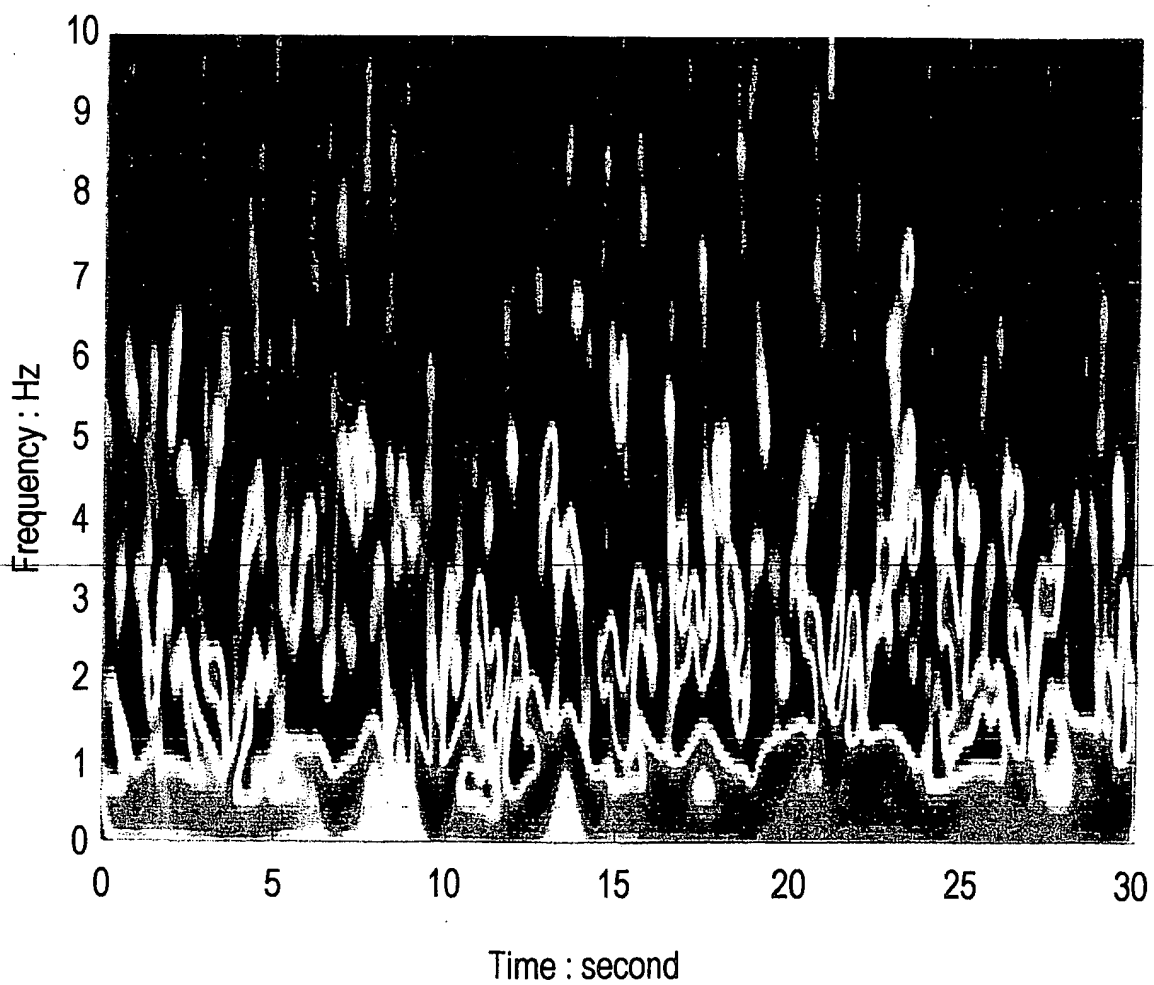
FIG. 7
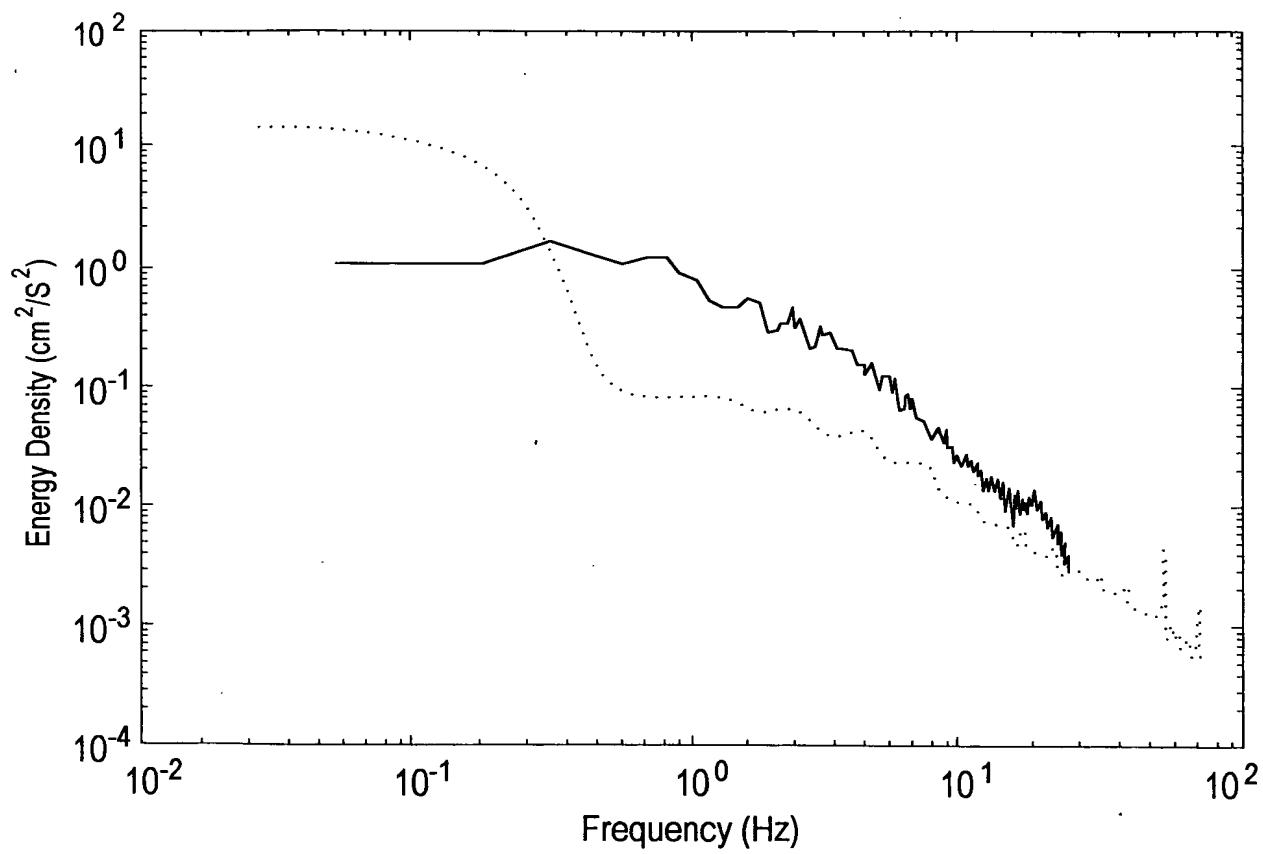
FIG. 8(a)
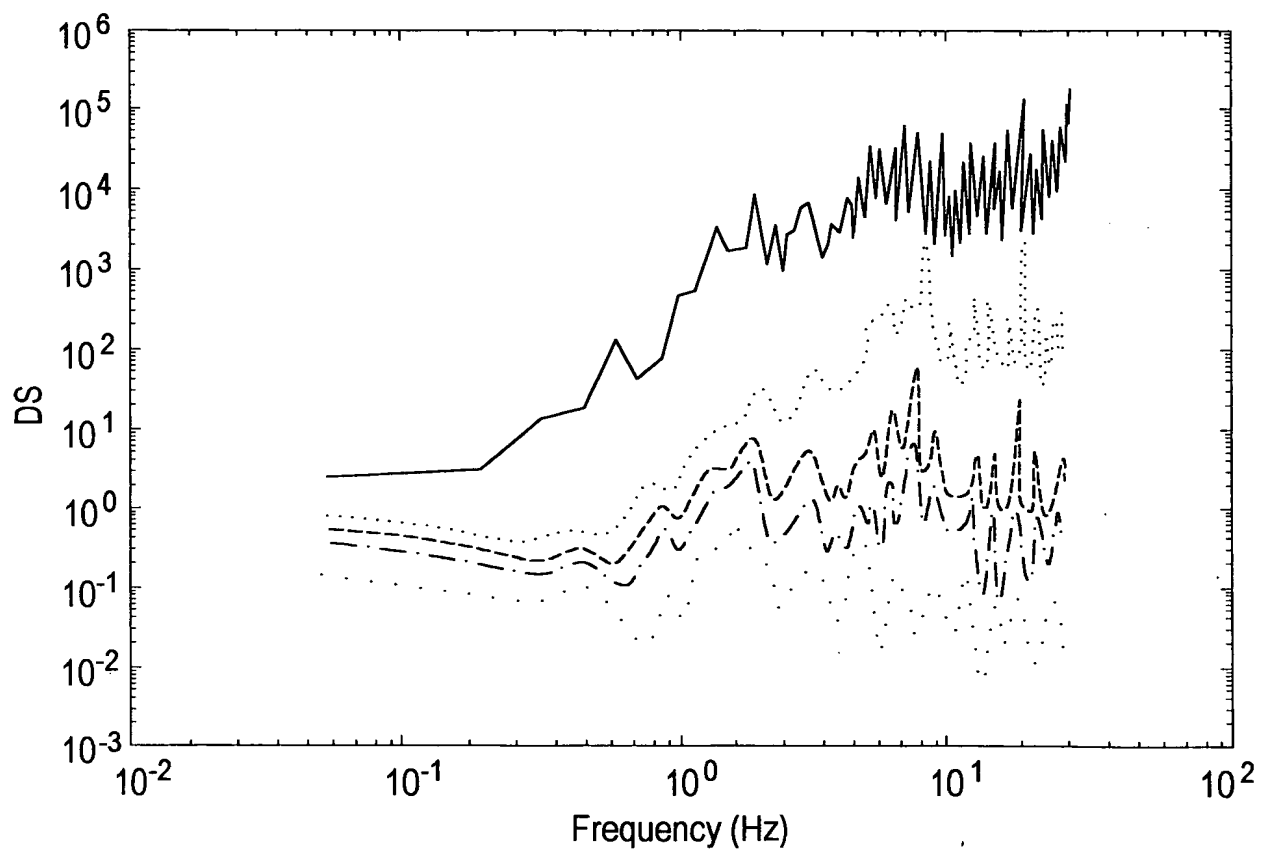
FIG. 8(b)
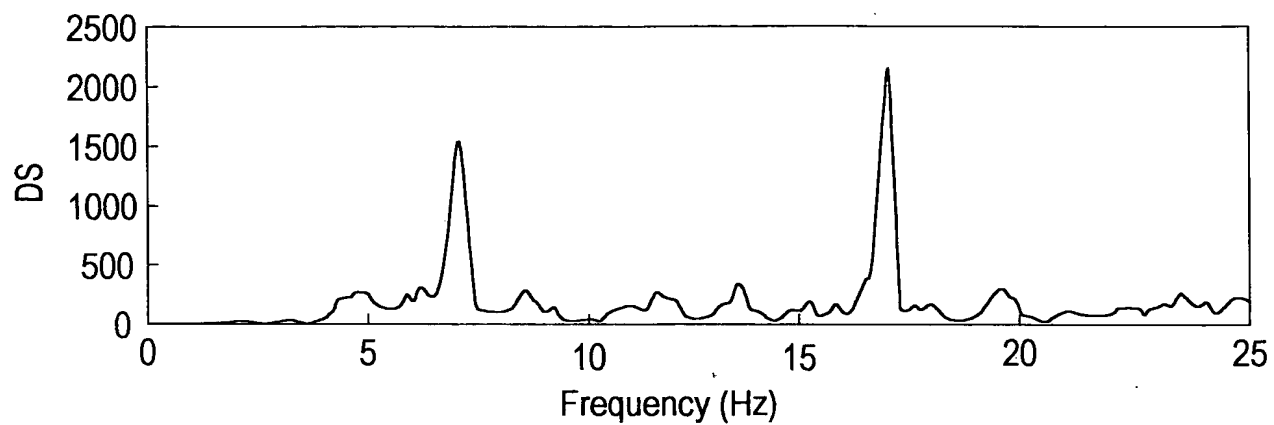
FIG. 8(c)
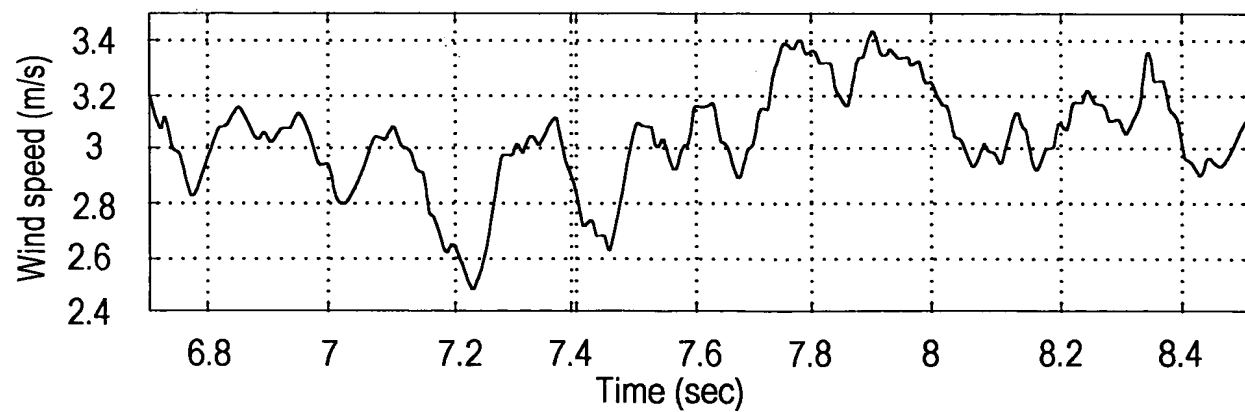
PULMONARY ARTERIAL PRESSURE OF RAT (24 HR.)
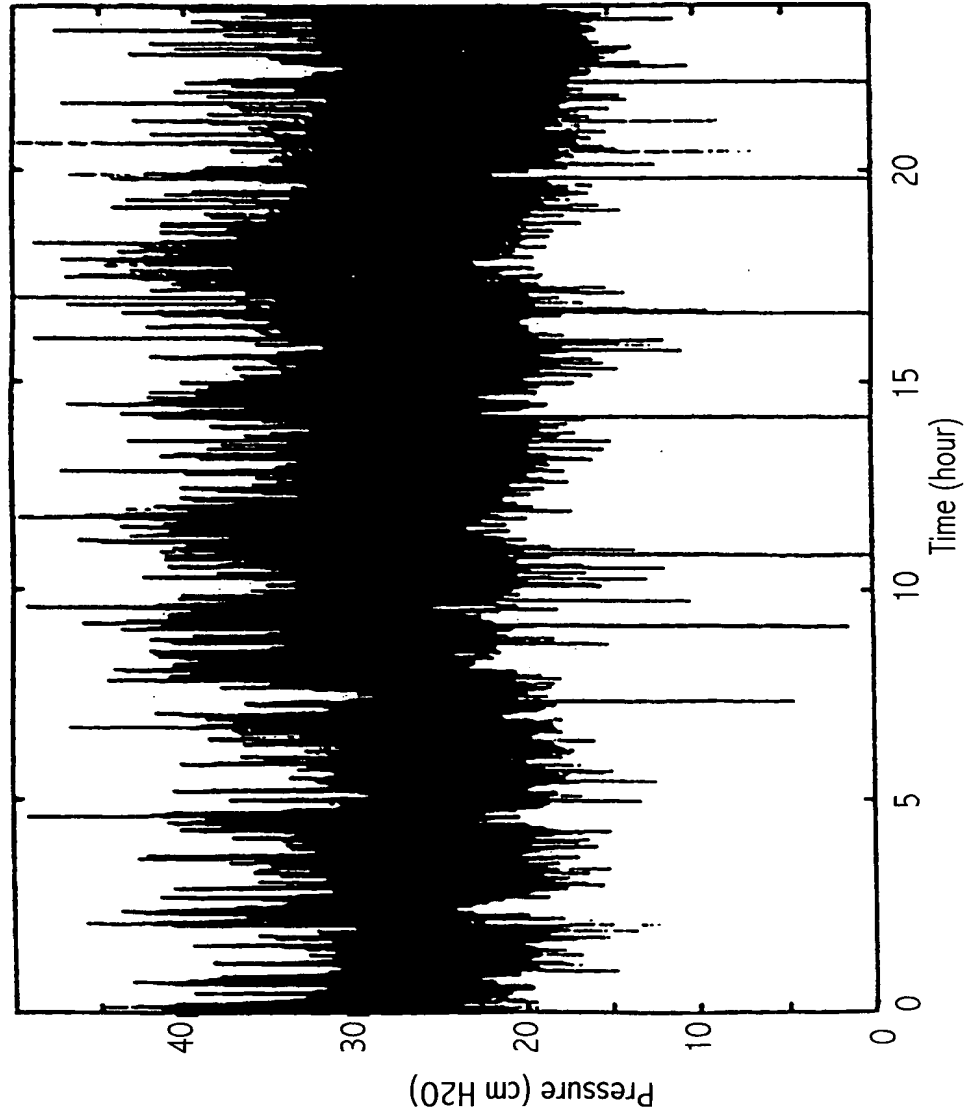
FIG. 9(a)

ONE HOUR STRIP

FIG. 9(b)

Time (hour)

Pressure (cm H2O)

FIG. 9(c)

FIG. 9(d)

FIG. 9(e)

Pressure (cm H2O)

50
40
30
20
10
0

393   398   403
Time (sec)
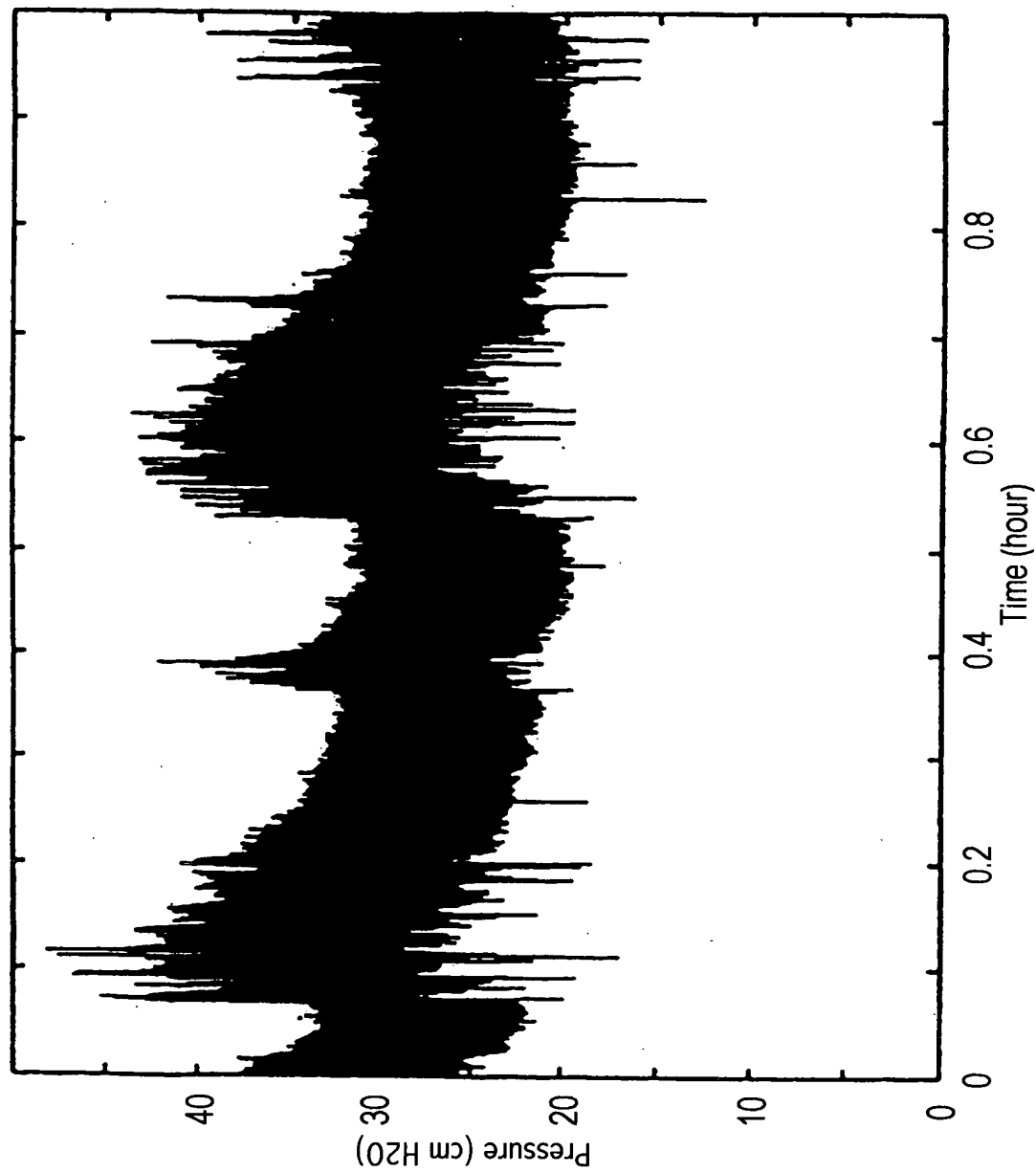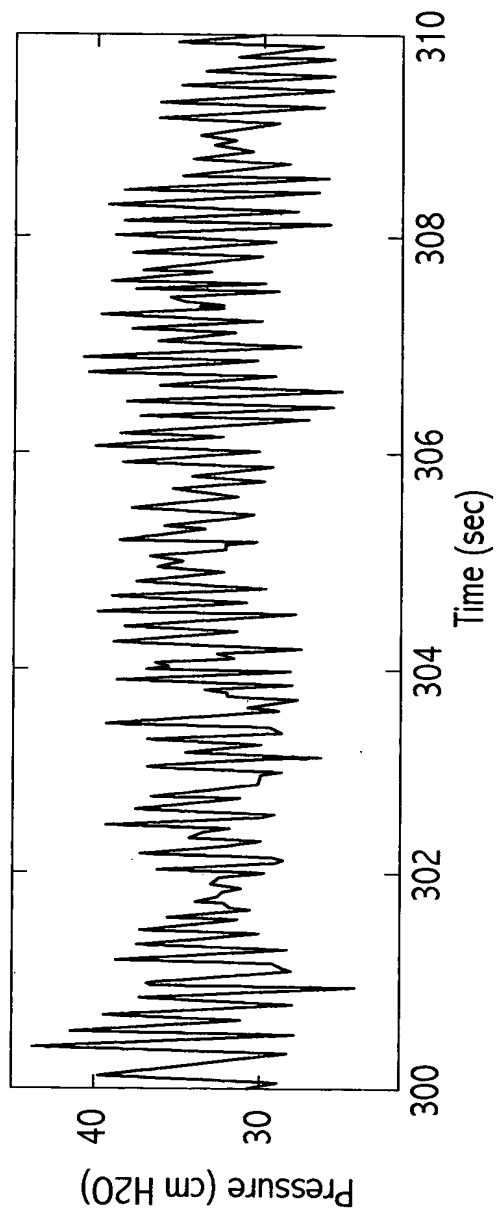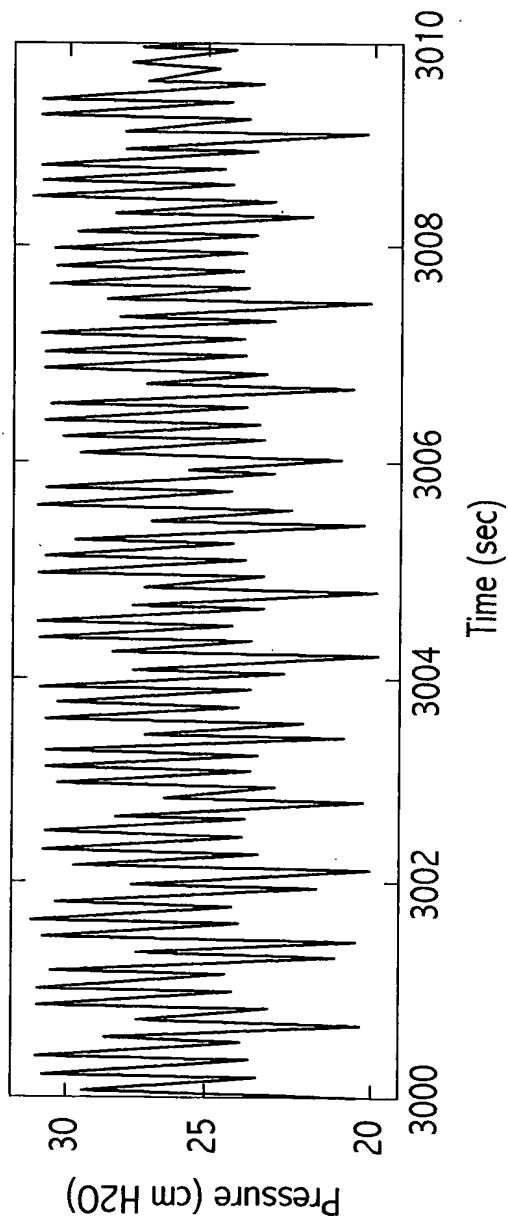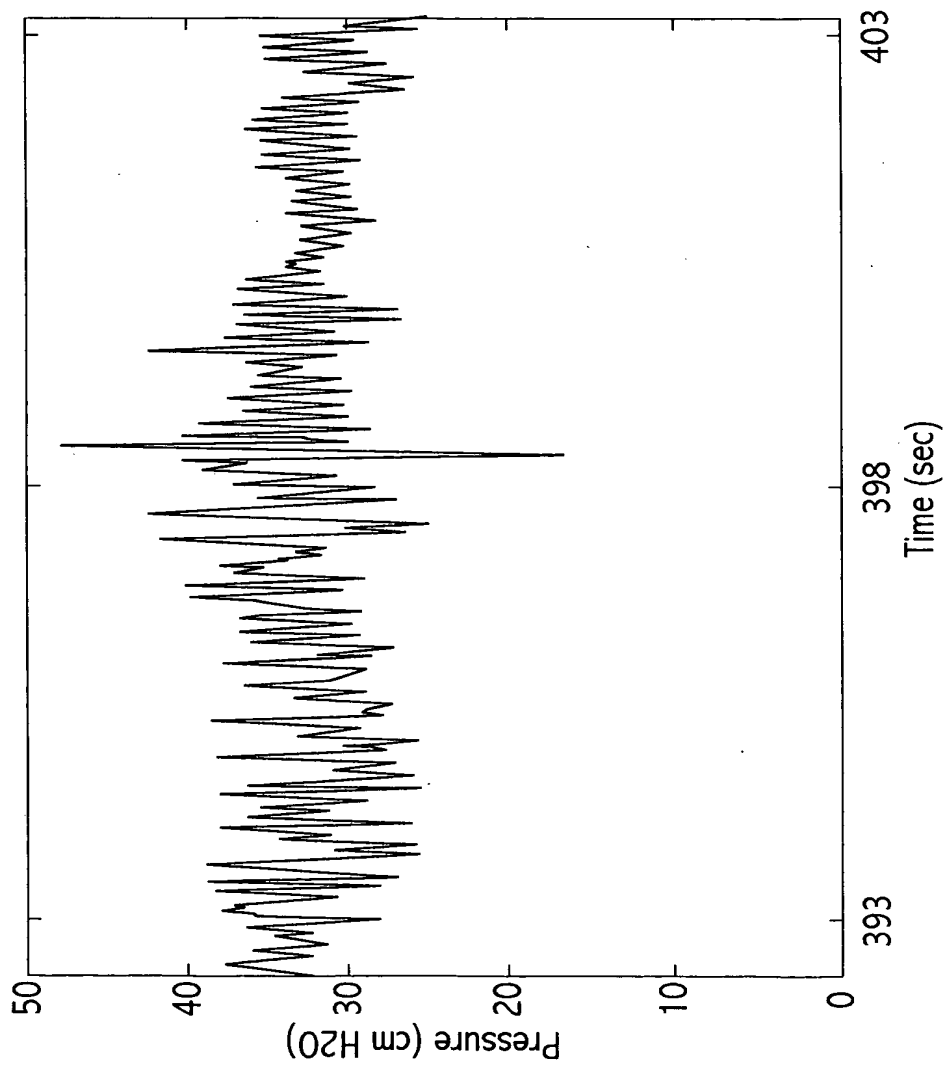
FIG. 9(f)

SYSTOLIC PRESSURES IN 1 HR.
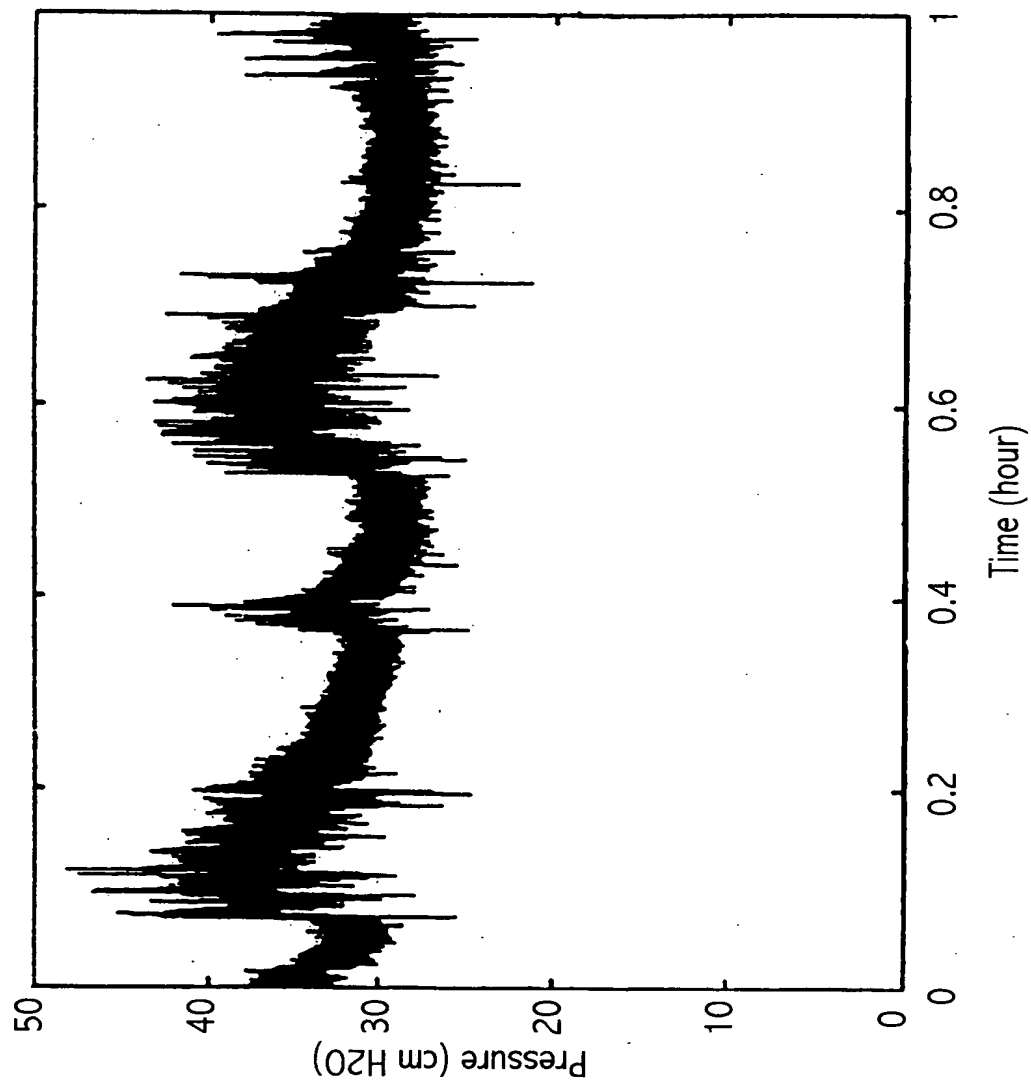
FIG. 9(g)

DIASTOLIC PRESSURES IN 1 HR.

FIG. 10(a)

FOURIER SPECTRUM OF THE FIRST HR. DATA

Energy vs. Frequency (Hz)
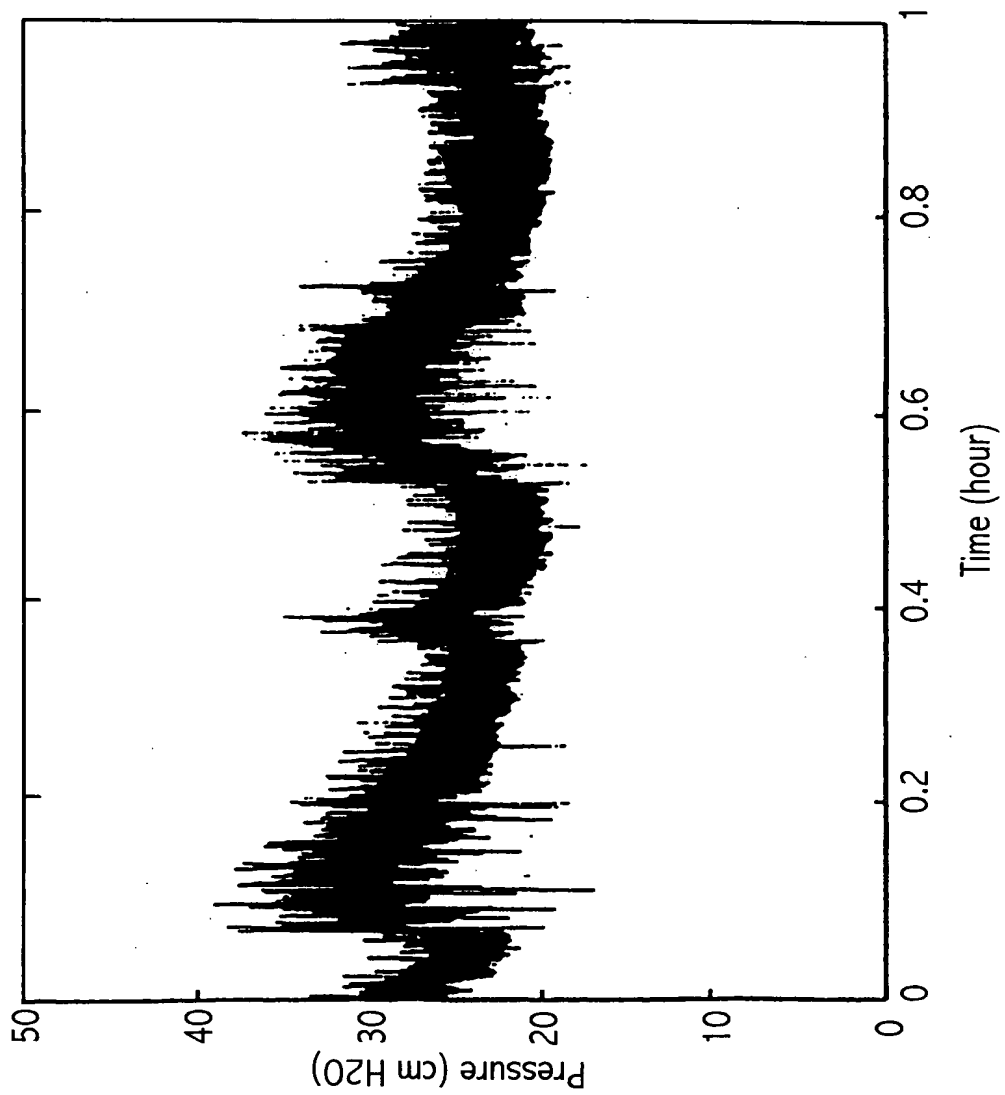
FOURIER SPECTRUM OF TWO 10-SEC STRIPS

FIG. 10(b)

FIG. 10(c)

FOURIER SPECTRUM OF THE FIRST HOUR DATA

FIG. 10(d)

FIG. 10(e)

Time (Hour)

Frequency (Hz)

1.5×10^7

1.0×10^7

0.5×10^7

FIG. 10(f)

FOURIER AND MARGINAL HILBERT SPECTRA, FIRST 10-SEC.
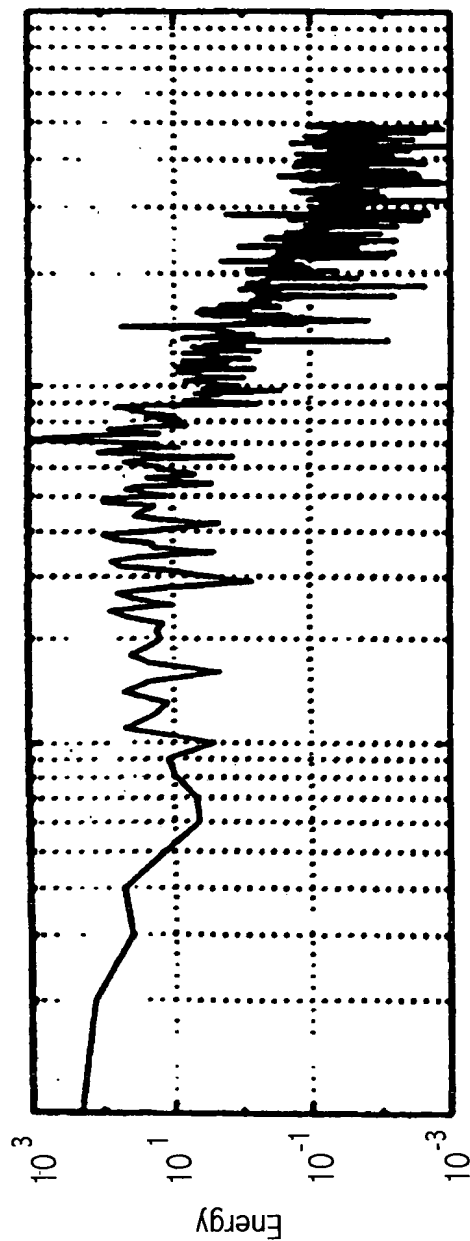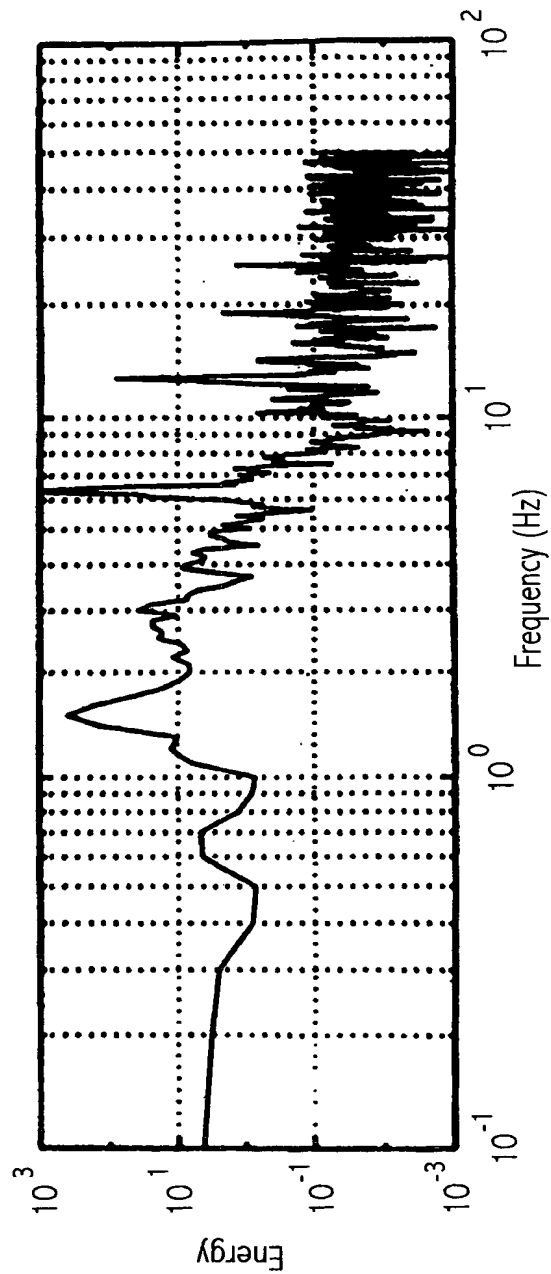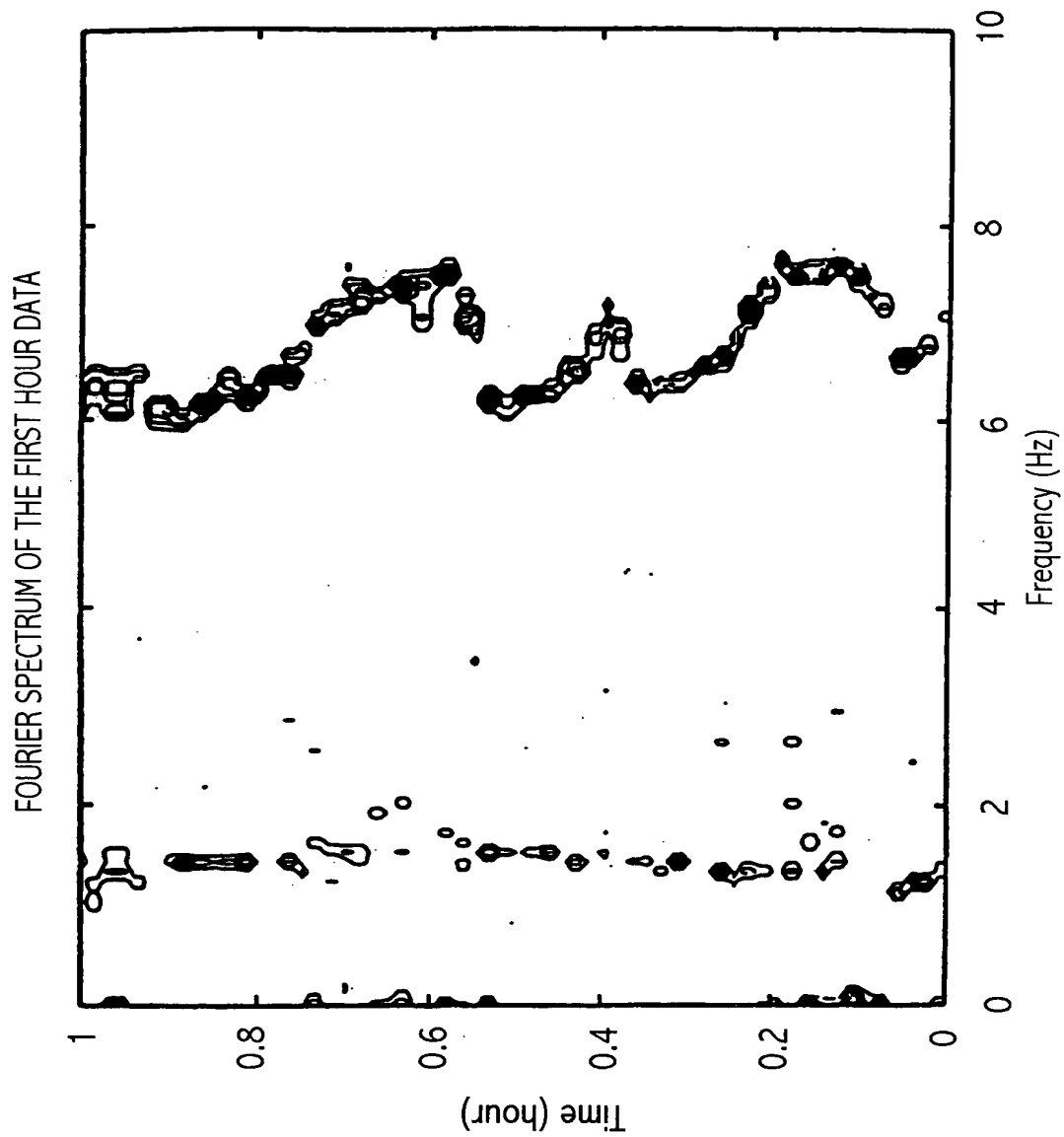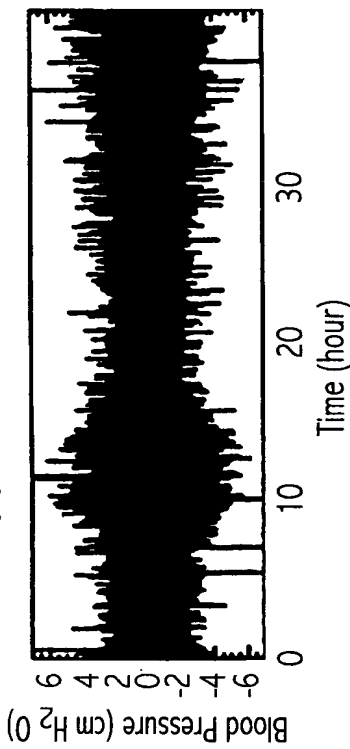

FIG. 10(g)

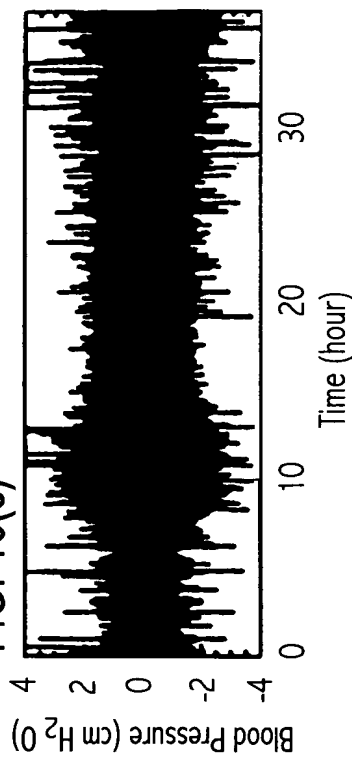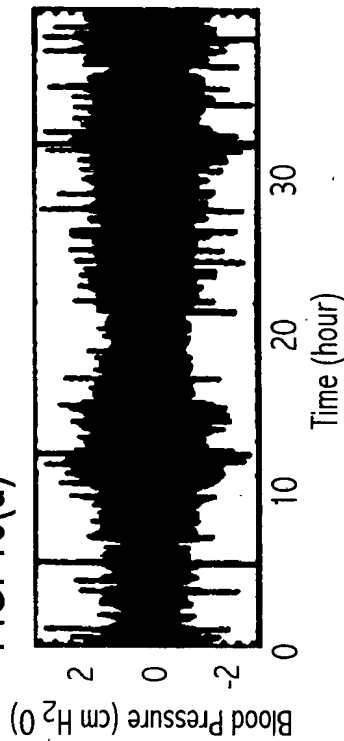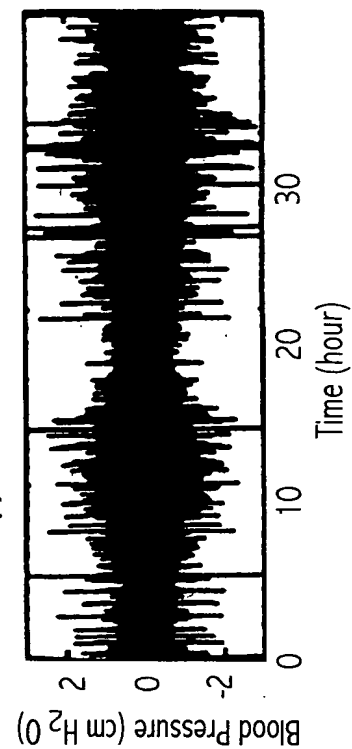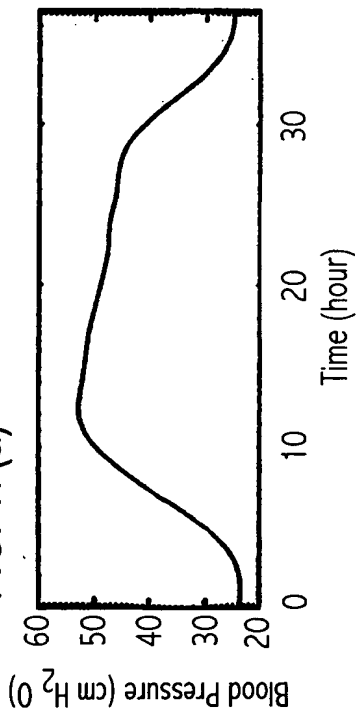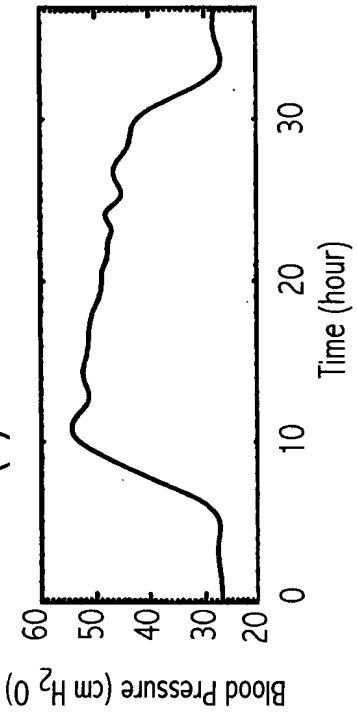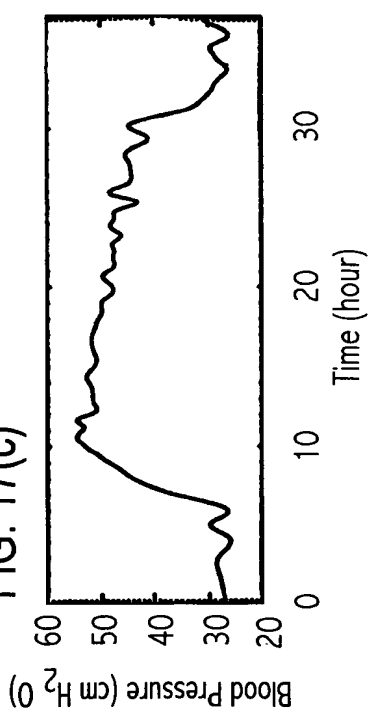IMF-COMPONENTS OF THE FIRST 10-SEC. STRIP

FIG. 11(a)

FIG. 11(b)

FIG. 11(c)

FIG. 11(d)

FIG. 11(e)

FIG. 11(f)

FIG. 11(g)

FIG. 11(h)

Time (sec)
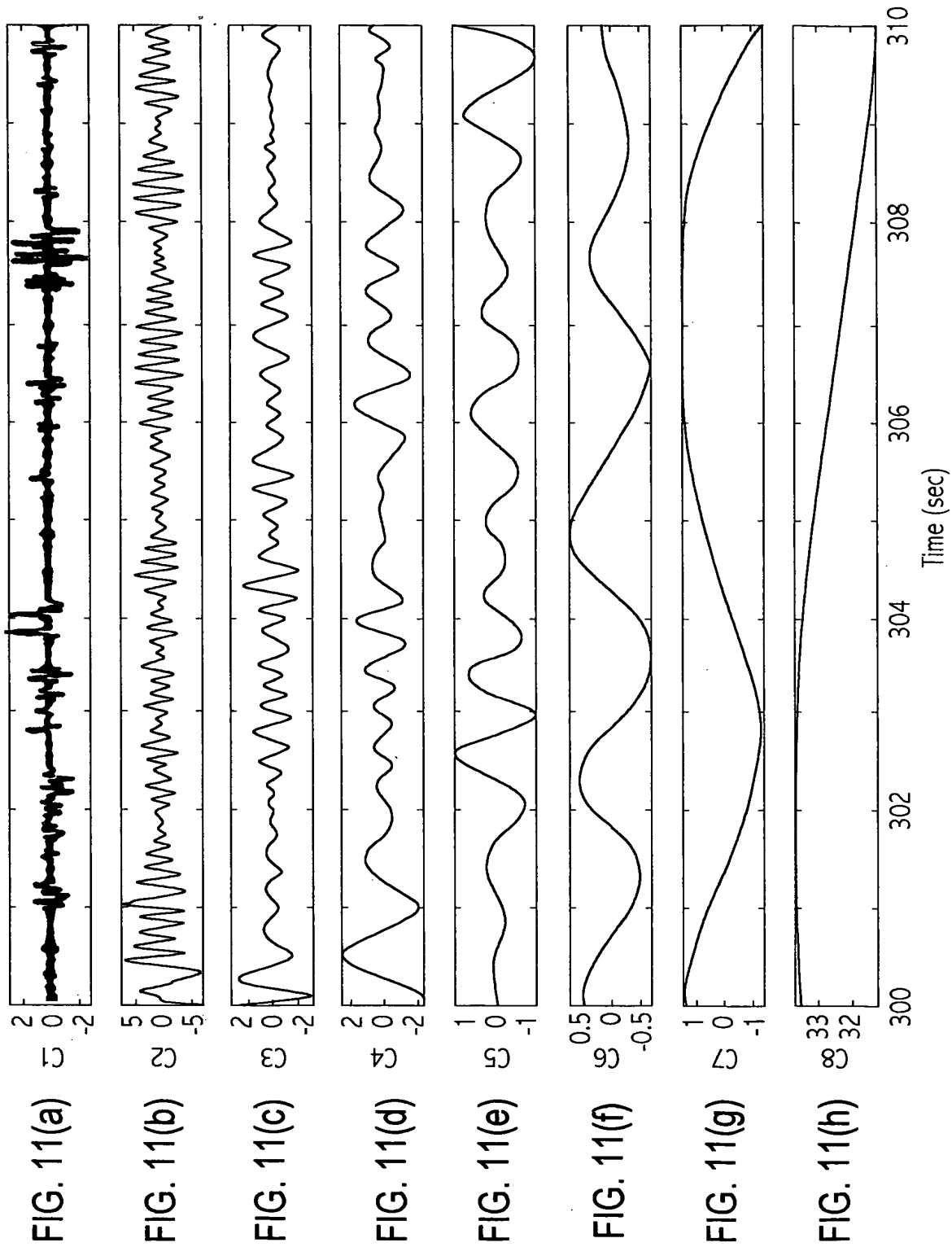
IMF-COMPONENTS OF THE SECOND 10-SEC. STRIP

FIG. 12(a)   C1

FIG. 12(b)   C2

FIG. 12(c)   C3

FIG. 12(d)   C4

FIG. 12(e)   C5

FIG. 12(f)   C6

FIG. 12(g)   C7

FIG. 12(h)   C8

Time (sec)
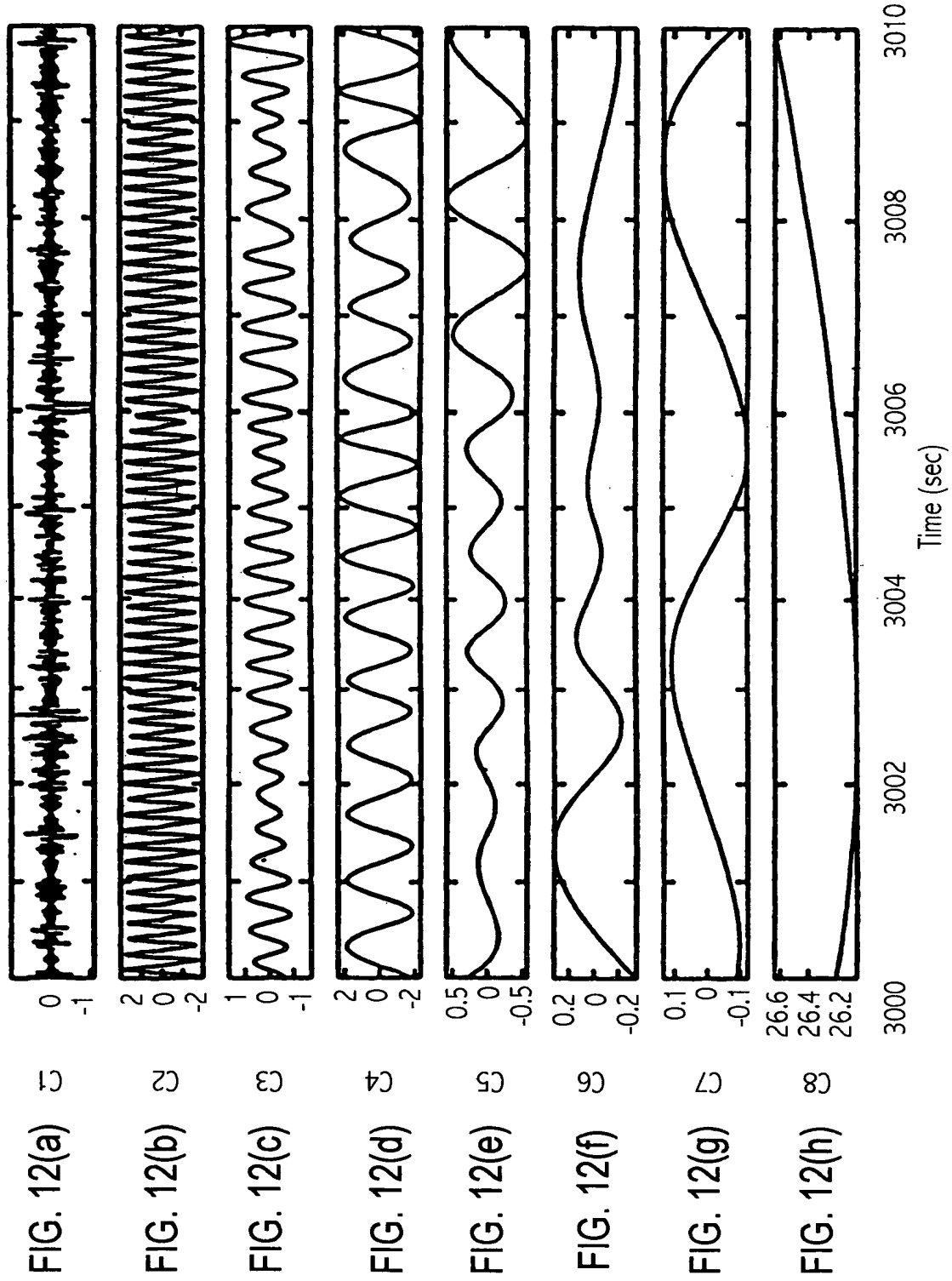
UPPER PANEL: C1+C2+C3; LOWER PANEL: C2+C3+C4

FIG. 13(a)

FIG. 13(b)

SUM C4 TO C8 OF THE SECOND 10-SEC STRIP

FIG. 13(c)

FIG. 15(h)

Blood Pressure (cm H$_2$O)

Time (sec)
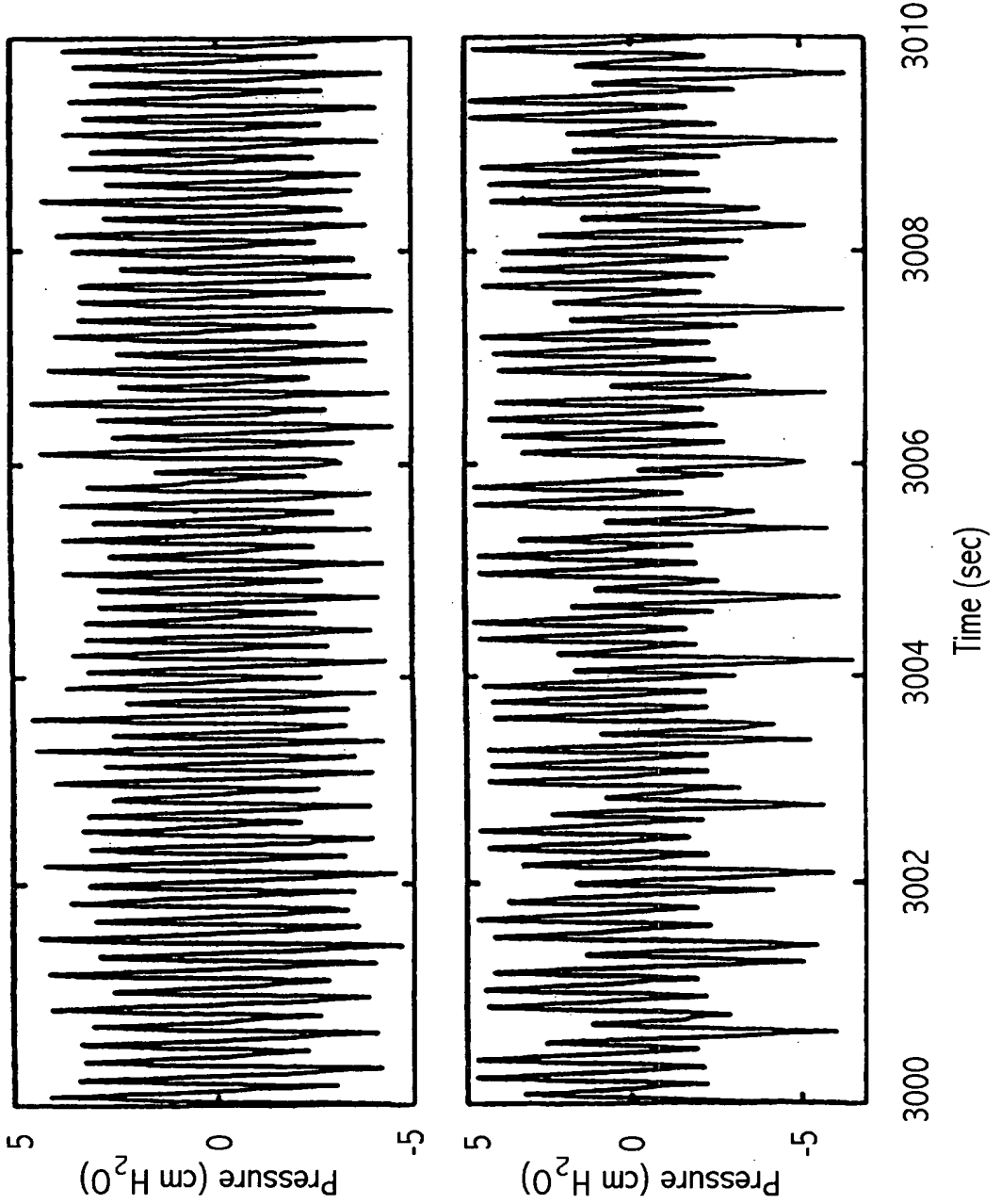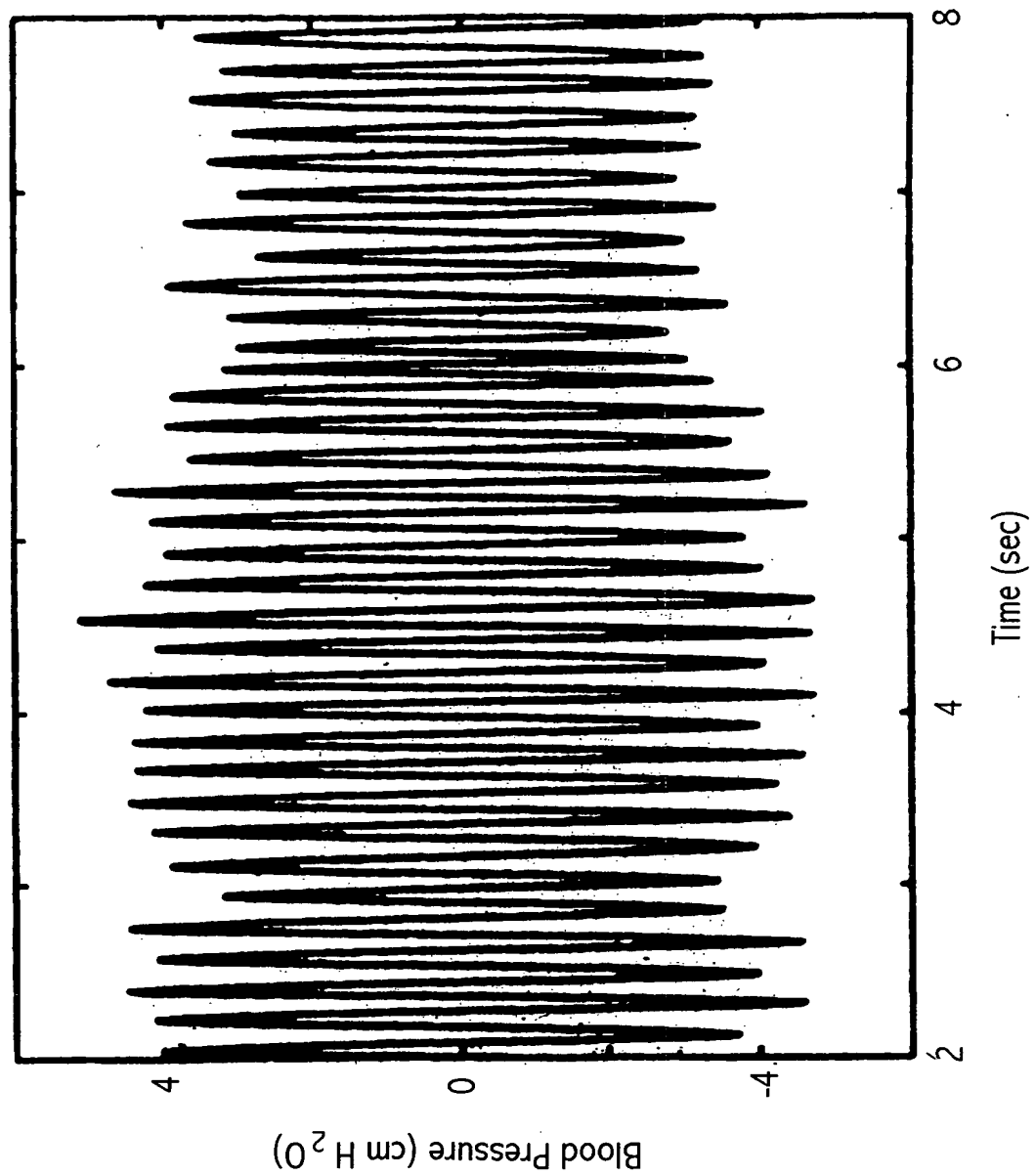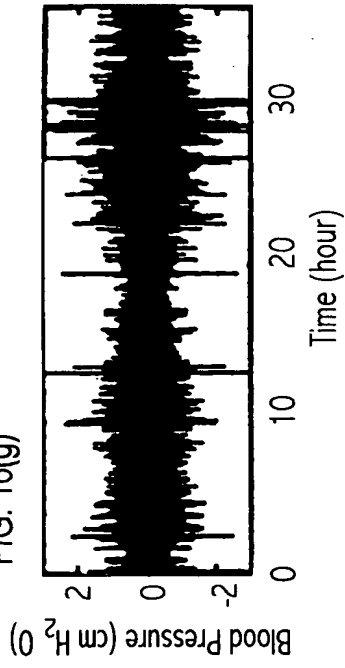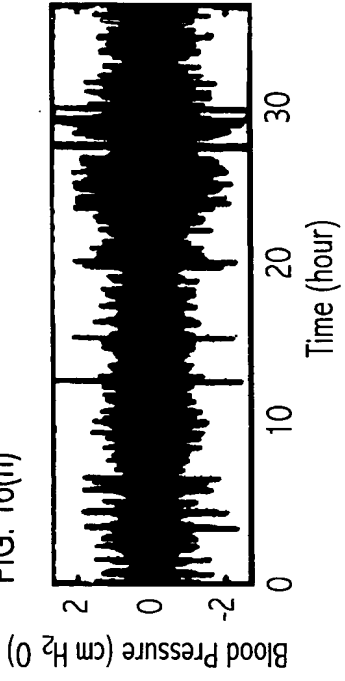
FIG. 16(g)
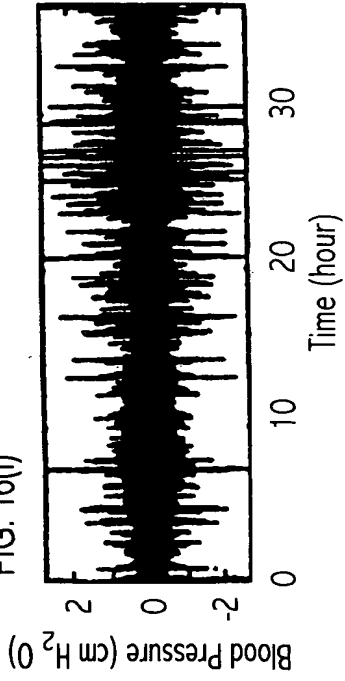
FIG. 16(h)

FIG. 16(i)

FIG. 16(j)

FIG. 16(k)

FIG. 16(l)

FIG. 18(a)

Blood Pressure (cm H_2O) vs Time (hour)

Legend: M(t), $M_{16}(t)$

$$M(t) = 29 + 11(t-t_0)e^{-(t-t_0)/4}$$

$$+15[1-e^{-(t-t_0)/5}]$$

$$\text{for } t > t_0 \quad t_0 = 6.6$$

FIG. 18(b)

Blood Pressure (cm H_2O) vs Time (hour)

Legend: M(t), $M_{14}(t)$

$$M(t) = 29 + 11(t-t_0)e^{-(t-t_0)/4}$$

$$+15[1-e^{-(t-t_0)/5}]$$

$$\text{for } t > t_0 \quad t_0 = 6.6$$

FIG. 18(c)

Blood Pressure (cm H_2O) vs Time (hour)

Legend: M(t), $M_{10}(t)$

$$M(t) = 29 + 5*60(t-t_0)e^{(t-t_0)/0.1}$$

$$+11(t-t_0)e^{(t-t_0)/4} + 15[1-e^{-(t-t_0)/5}]$$

$$\text{for } t > t_0 \quad t_0 = 6.6$$

FIG. 19(a)

$M(t)=40+12[e^{-0.3(t-30.8)}-1]$

for $t>30.8$

FIG. 19(b)

$M(t)=40+12[e^{-1.4(t-30.8)}-1]$ for $t>30.8$

FIG. 19(c)

for $t>30.8$

$M(t)=40+12[e^{-1.7(t-30.8)}-1]$
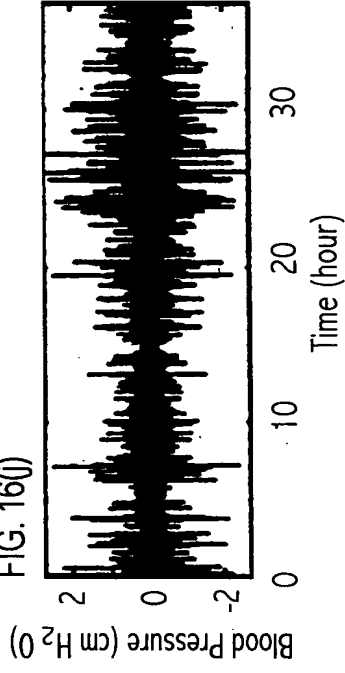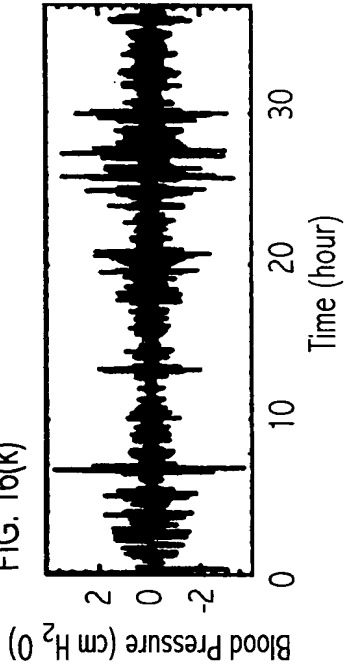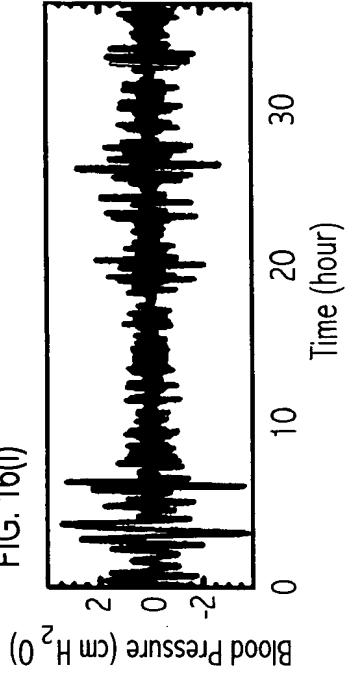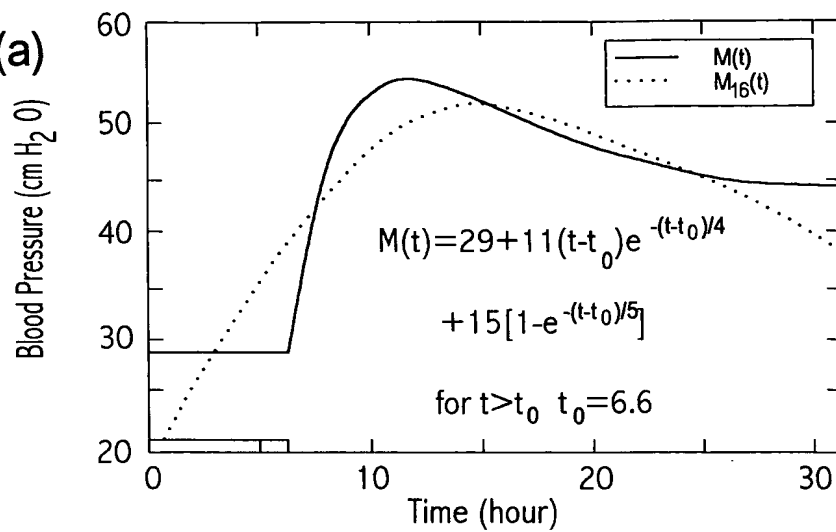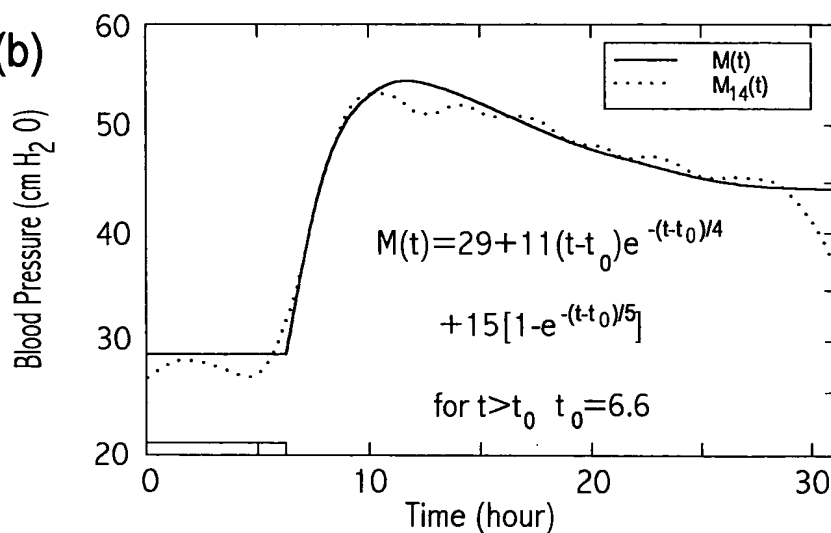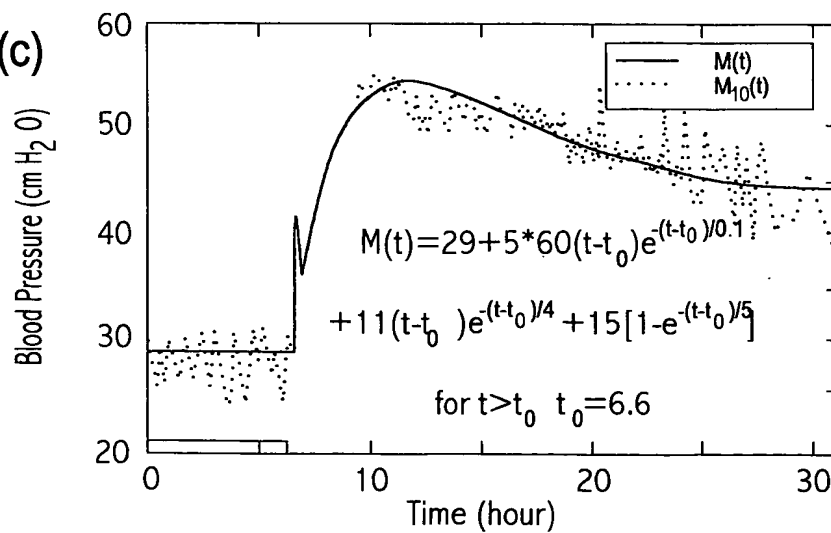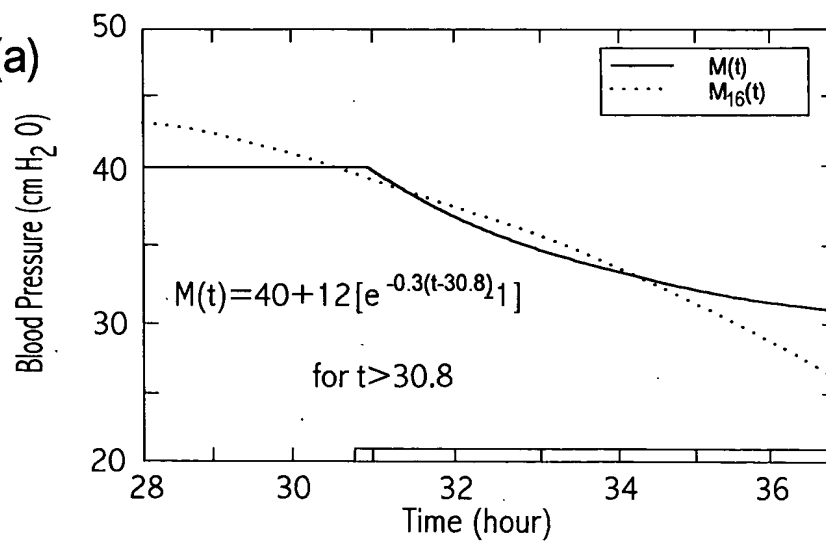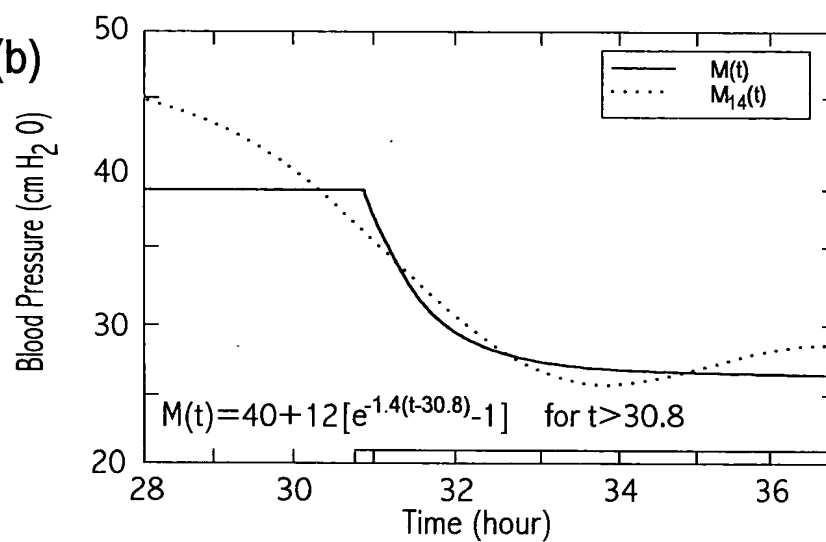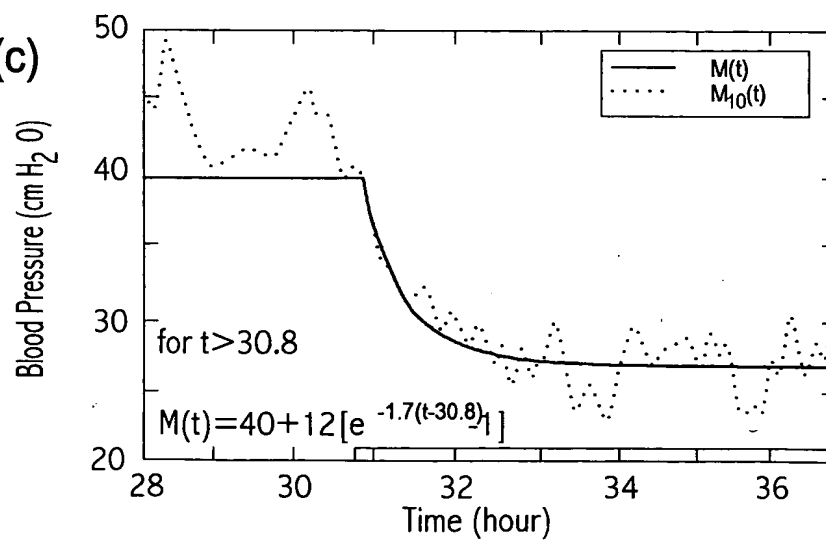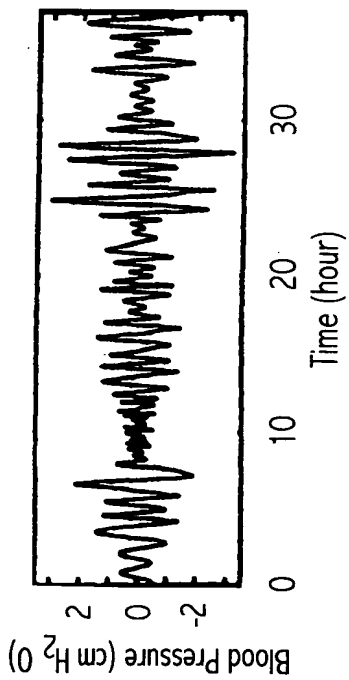
FIG. 16(m)

FIG. 16(n)

FIG. 16(o)

FIG. 16(p)

FIG. 15(g)

Blood Pressure (cm H$_2$O)

Time (sec)

HHT-SPECTRUM OF THE SECOND 10-SEC STRIP
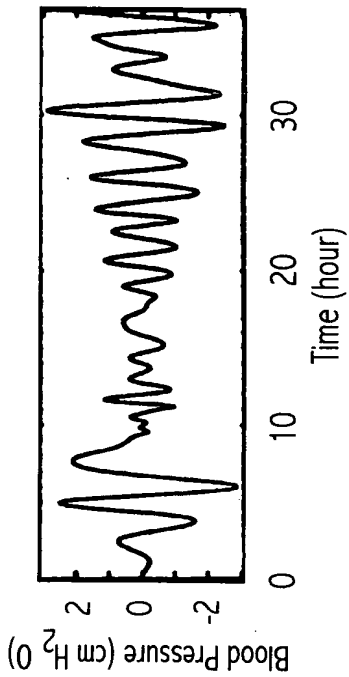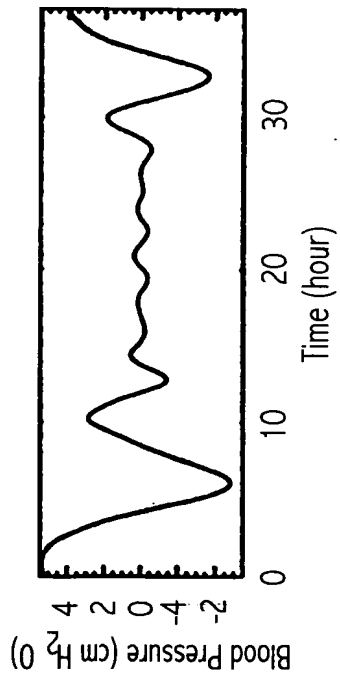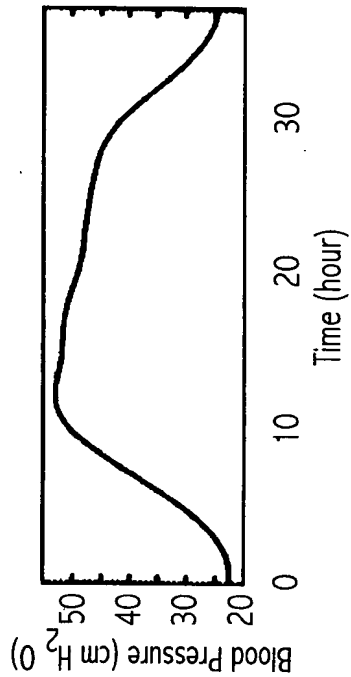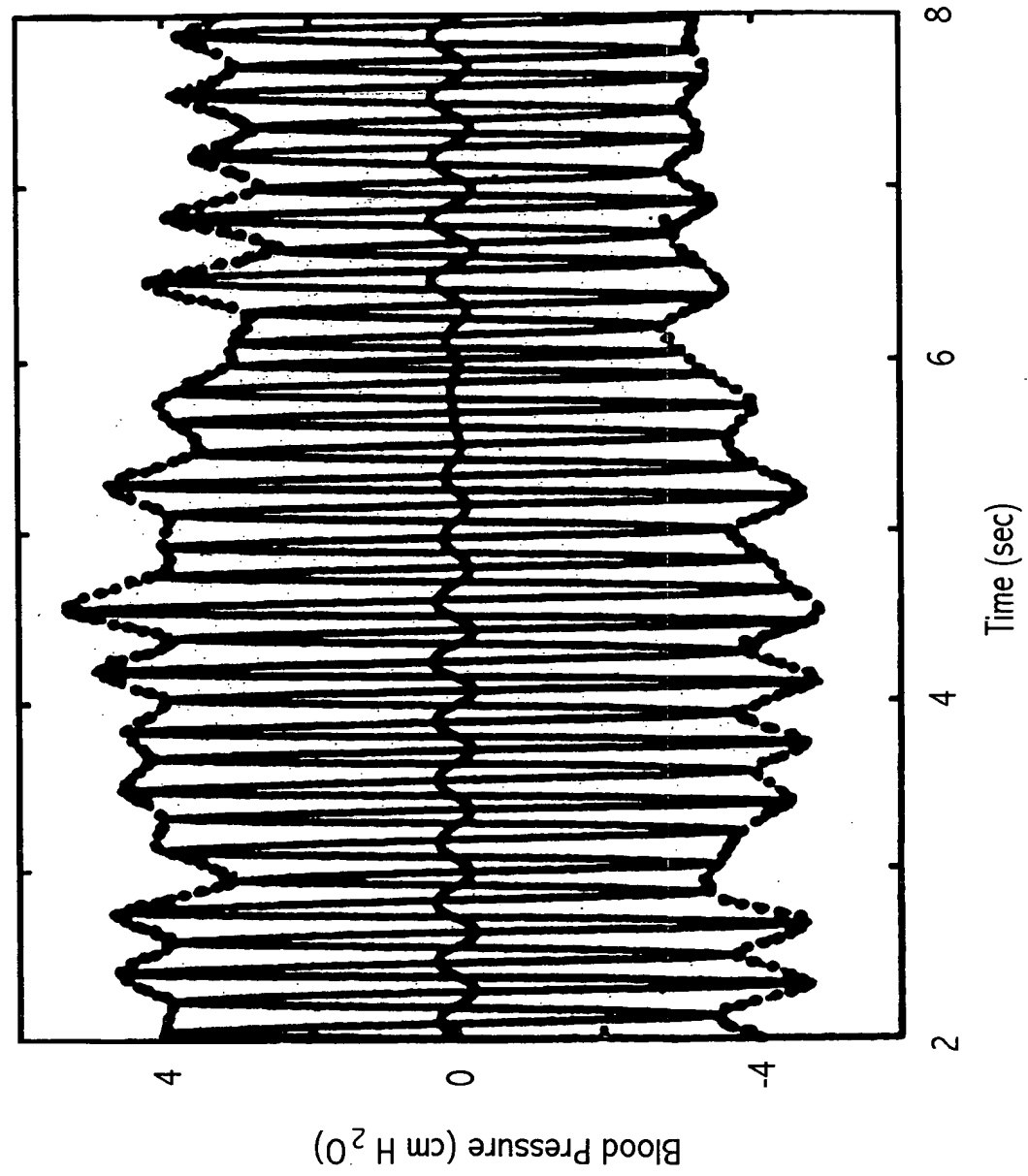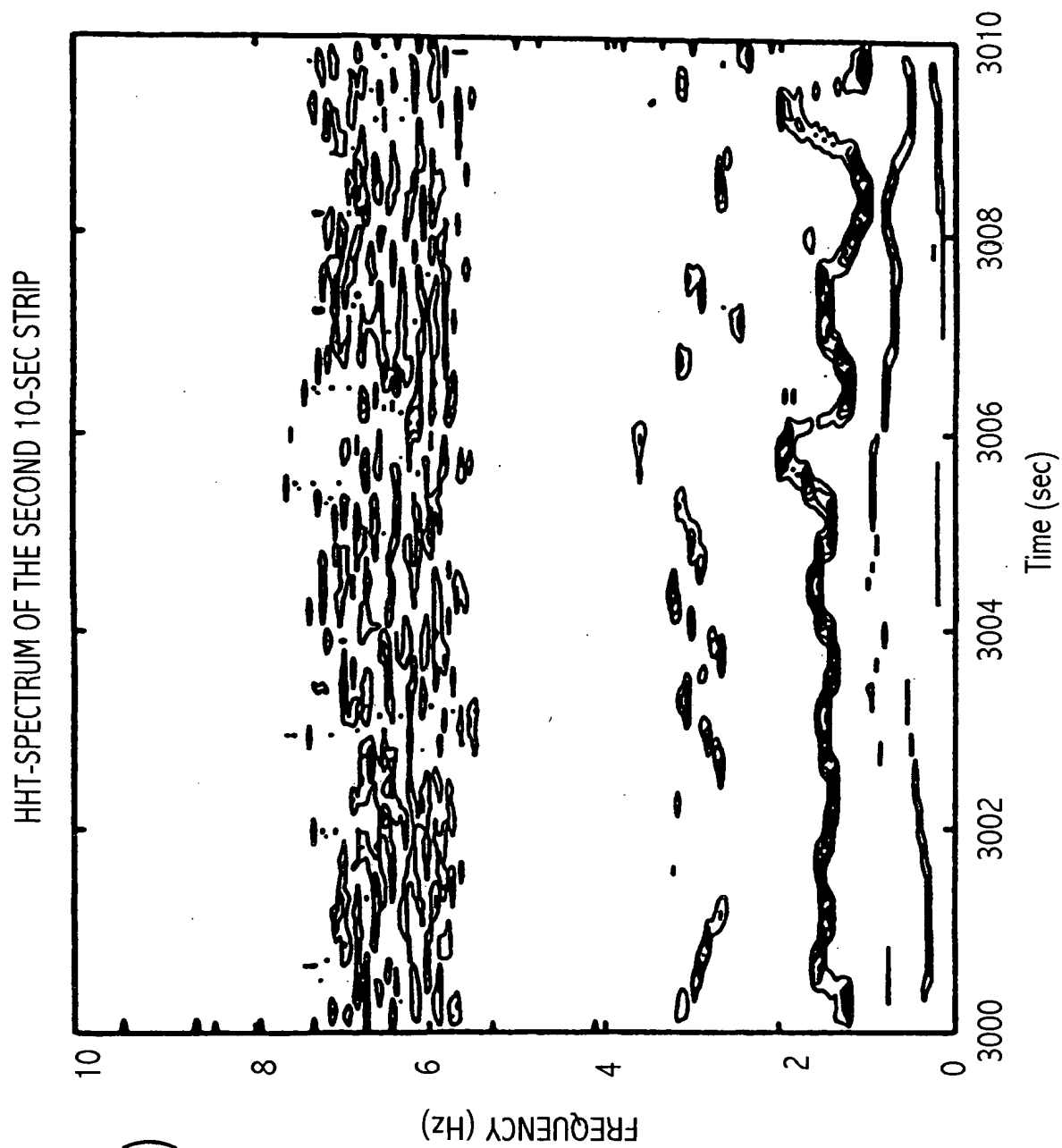
FIG. 14(a)

FIG. 14(b)

HHT-SPECTRUM OF THE FIRST 10-SEC STRIP

FIG. 15(a)

OXYGEN CONC. (%)

PRESSURE

O_2

Pressure (cm H_2O)

Time (Hour)

FIG. 15(b)

FIG. 15(c)

FIG. 15(d)

FIG. 15(e)

Blood Pressure (cm H_2O)

Time (sec)
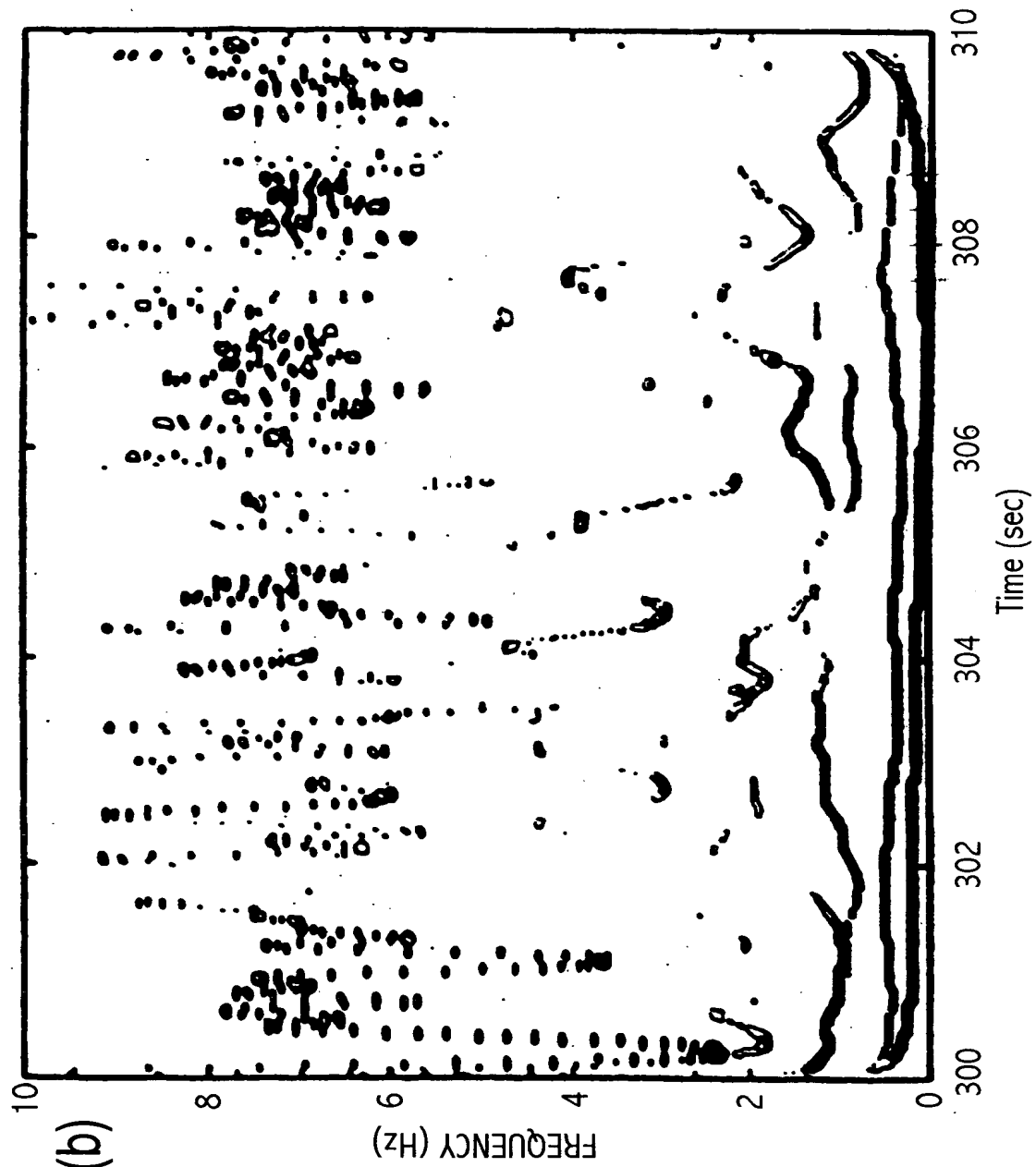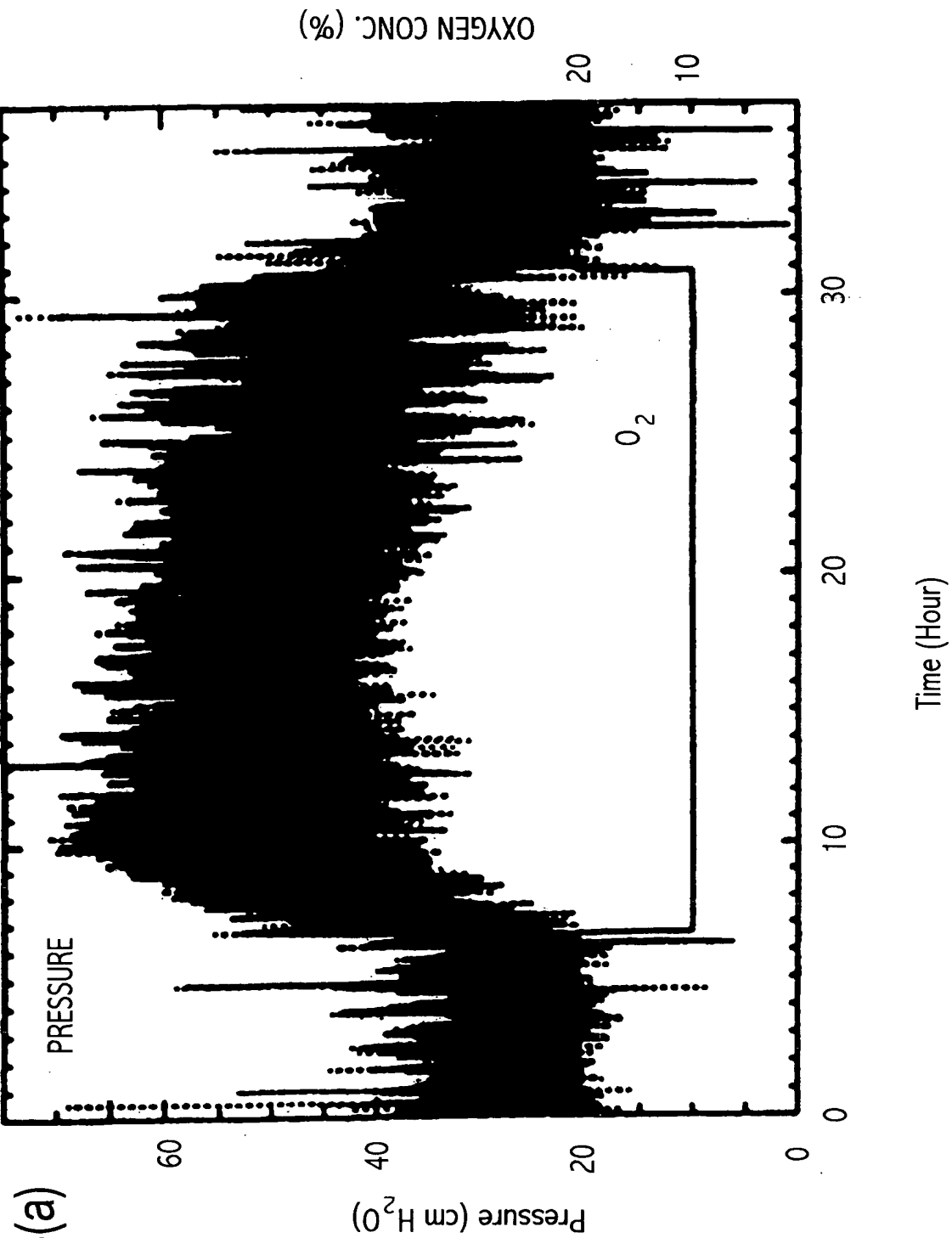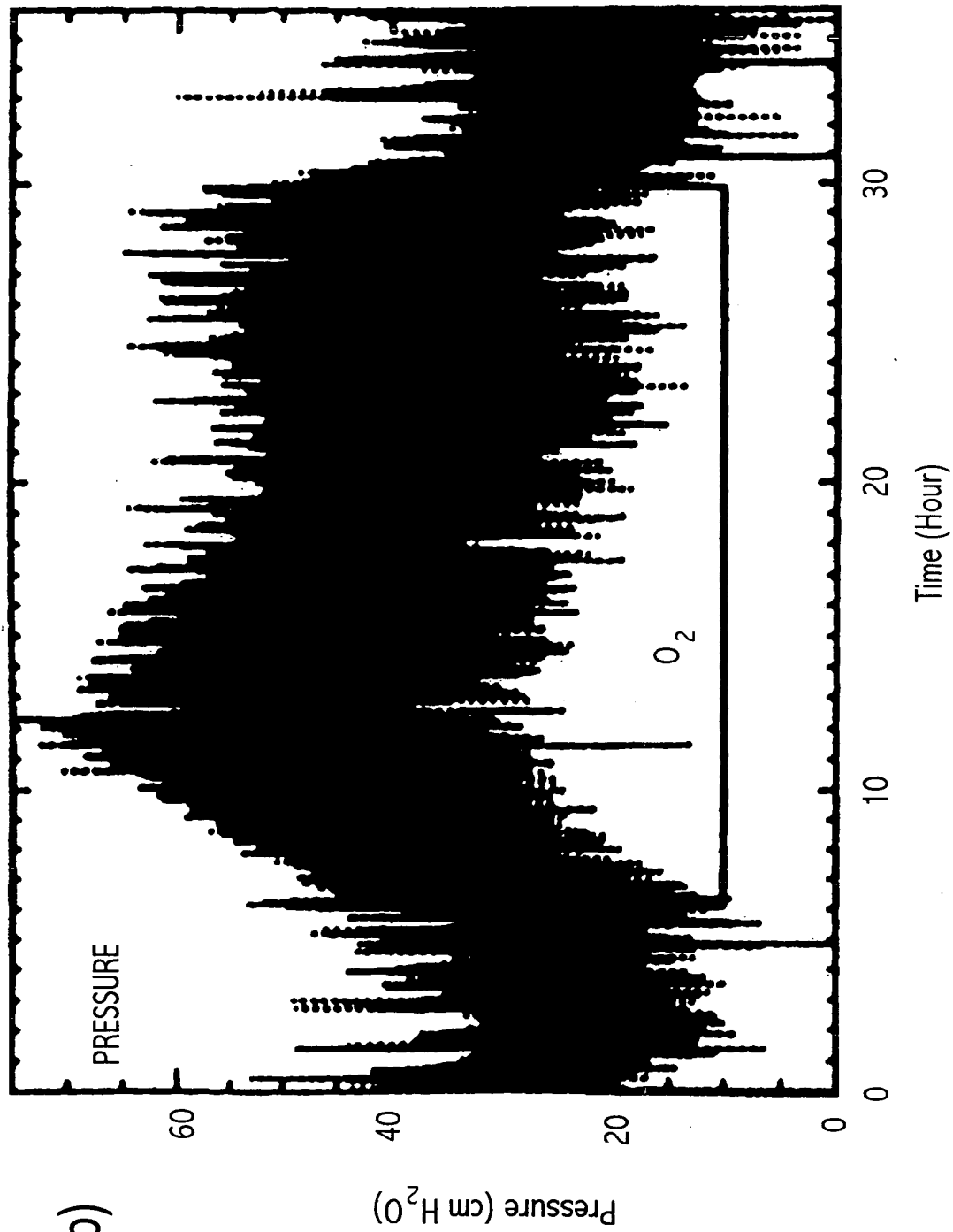
FIG. 15(f)
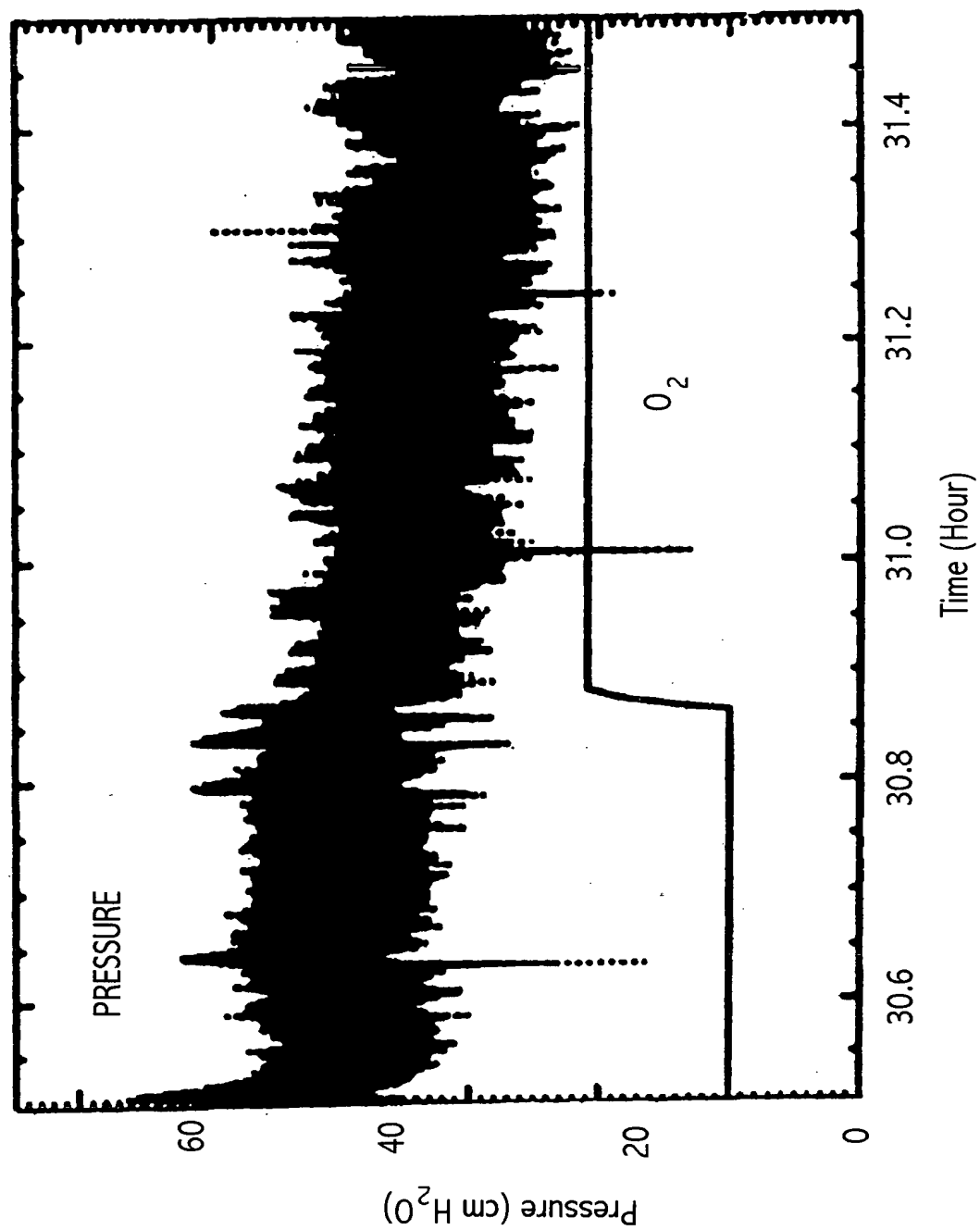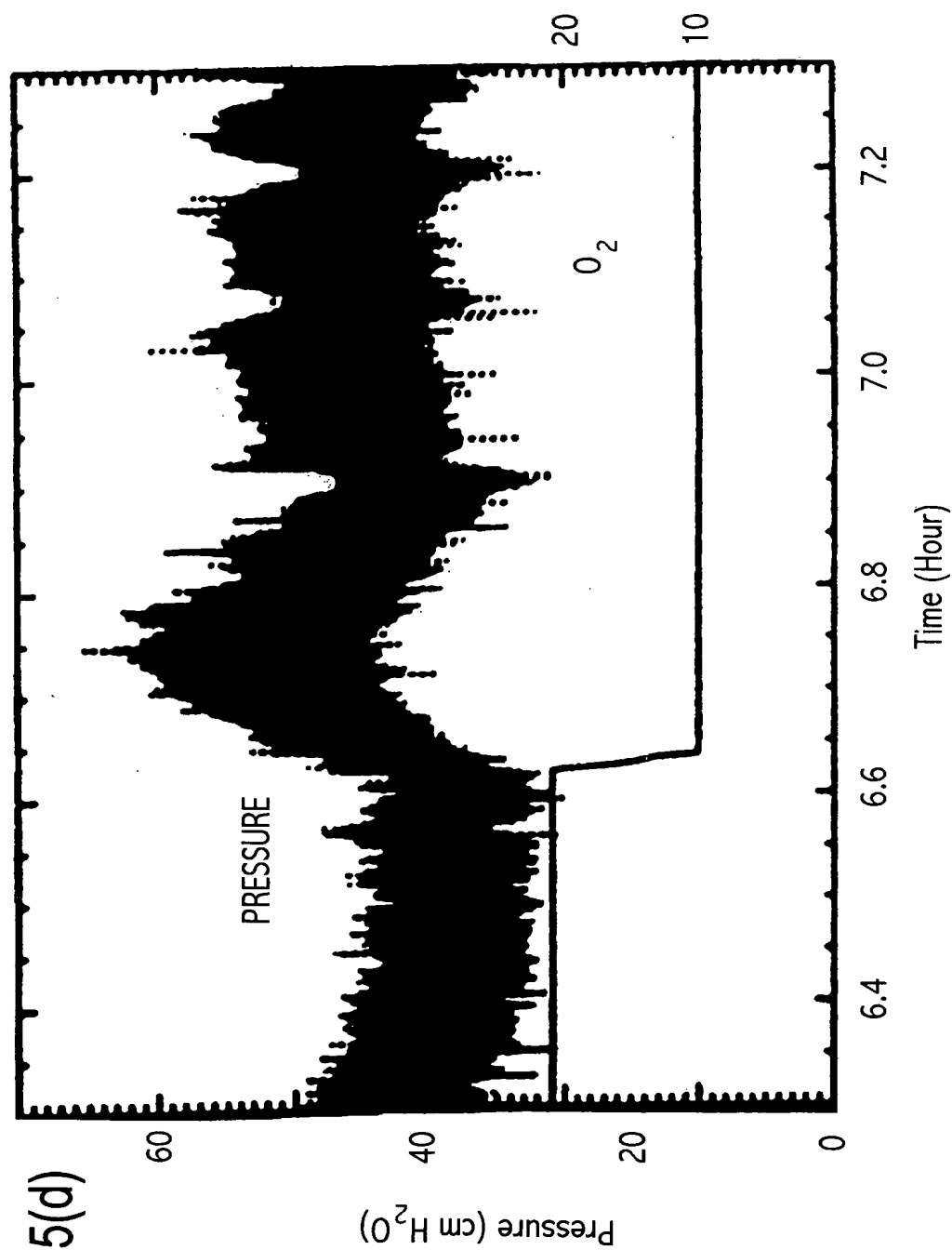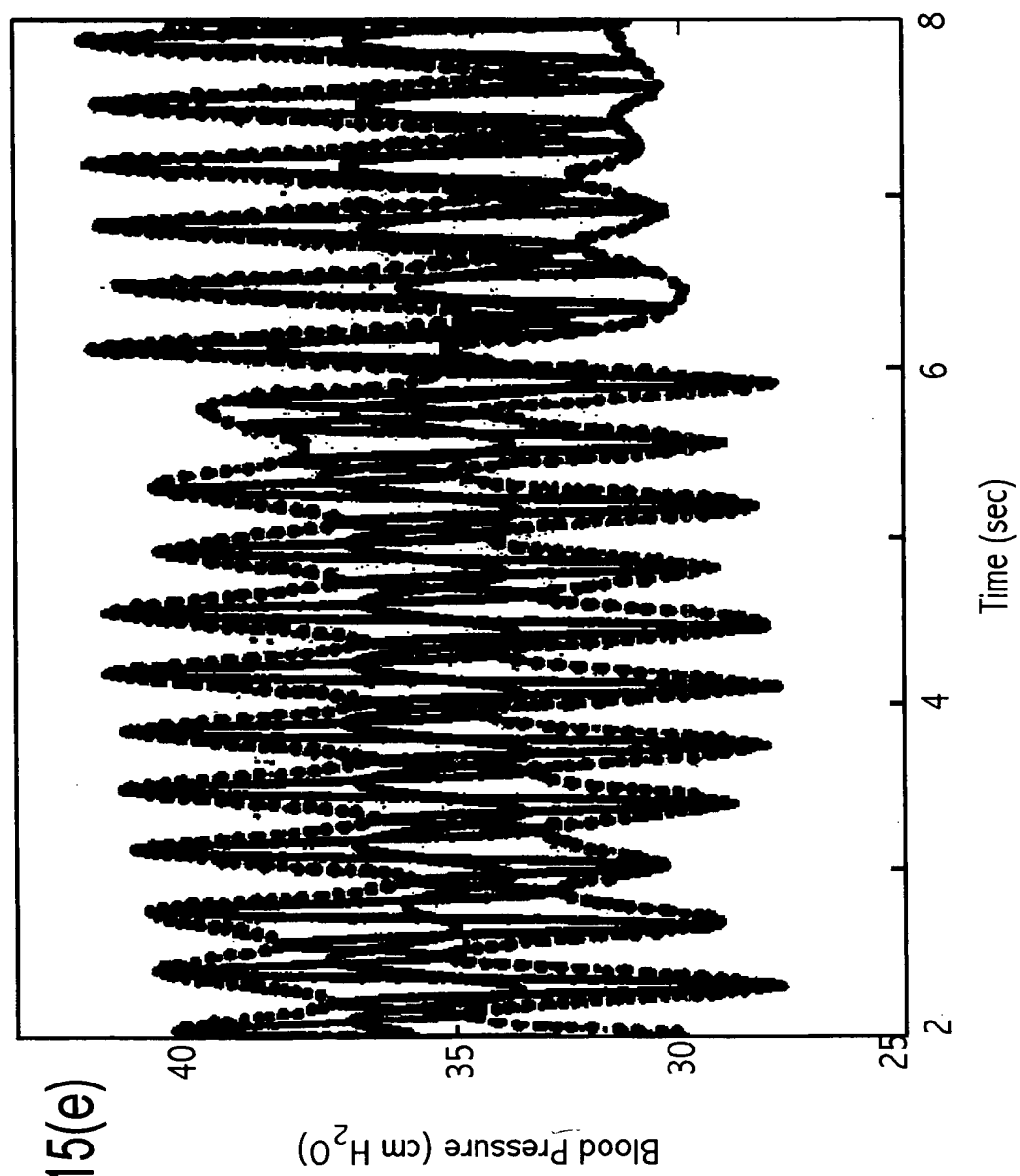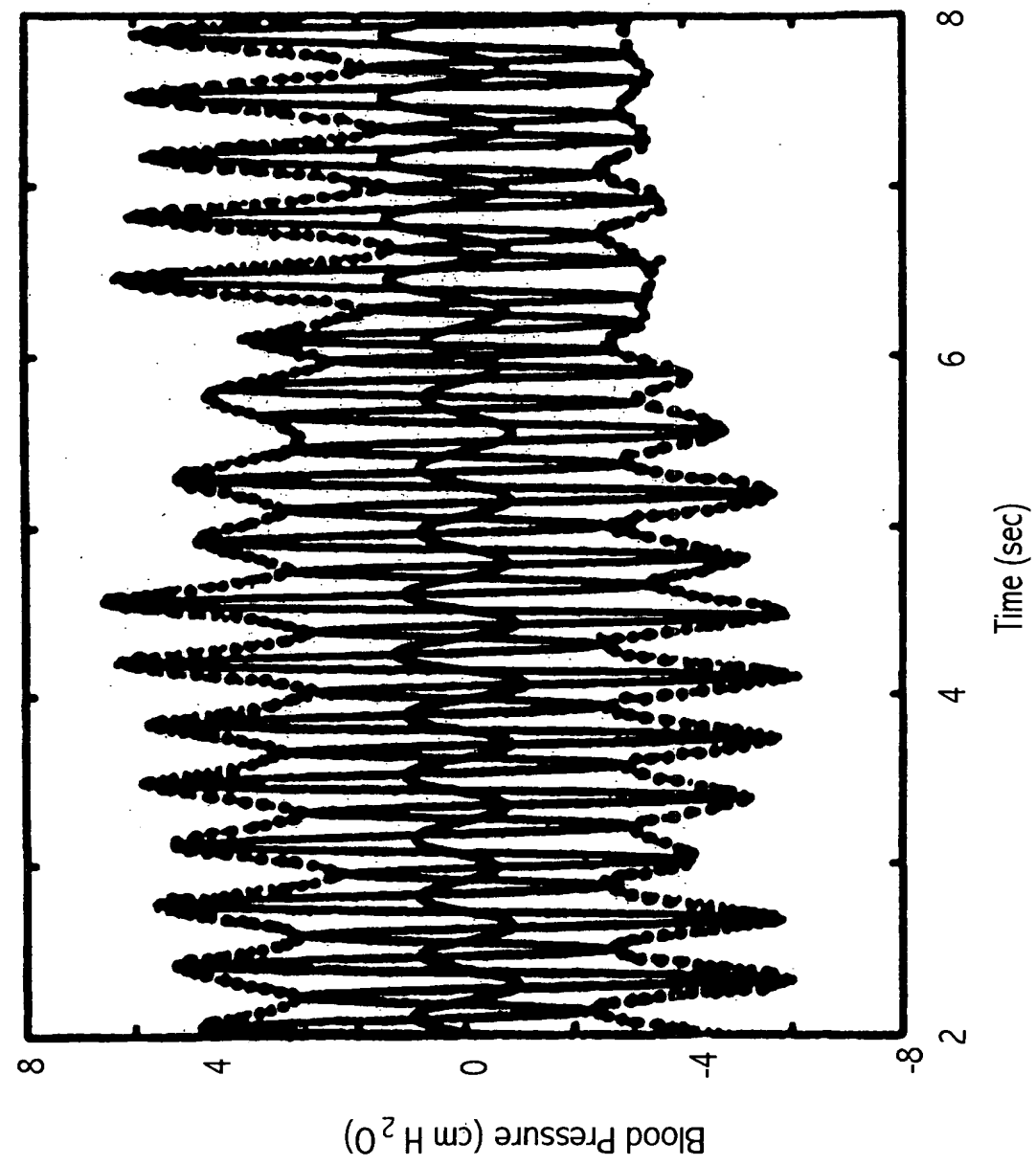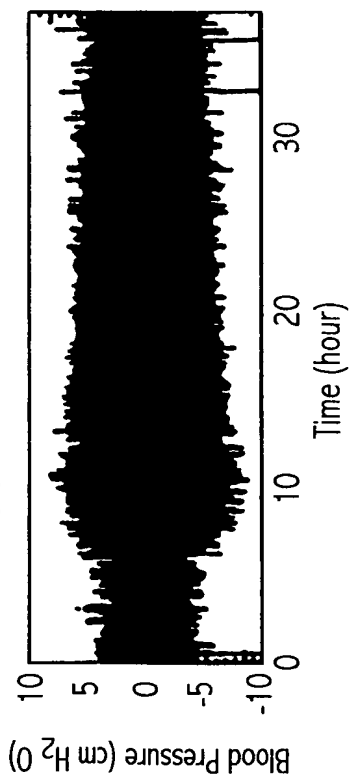
FIG. 16(a)   FIG. 16(b)   FIG. 16(c)   FIG. 16(d)   FIG. 16(e)   FIG. 16(f)
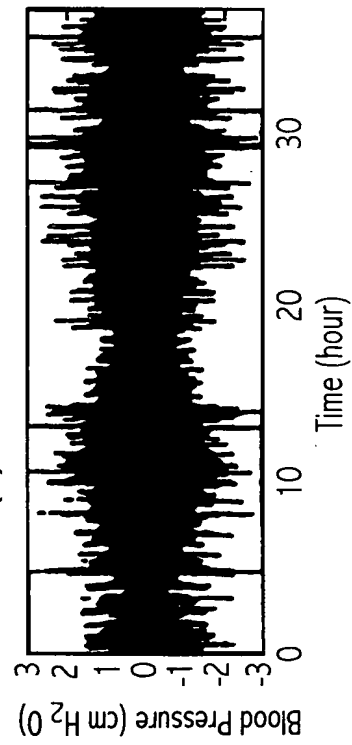
FIG. 17(a)

FIG. 17(b)

FIG. 17(c)

FIG. 17(d)
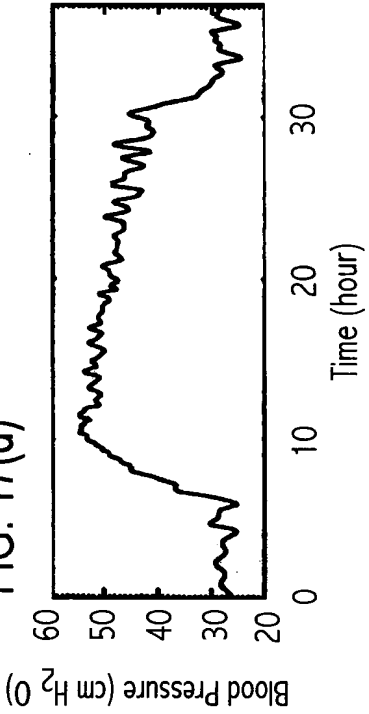
FIG. 17(e)
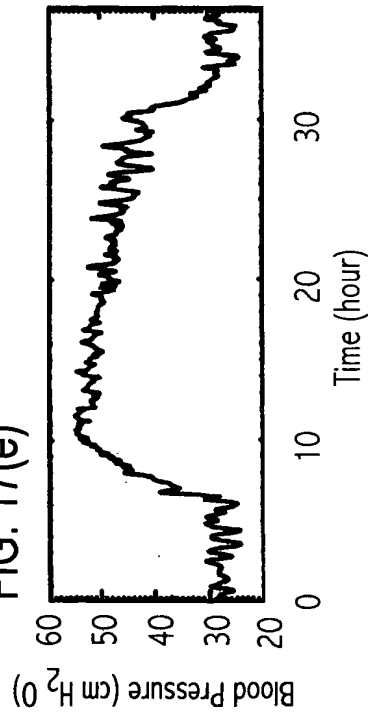
FIG. 17(f)
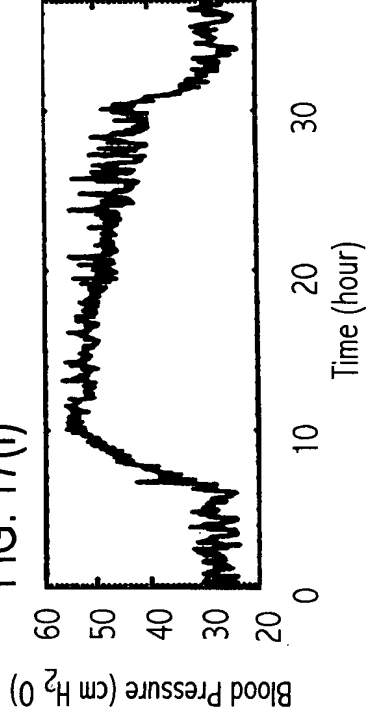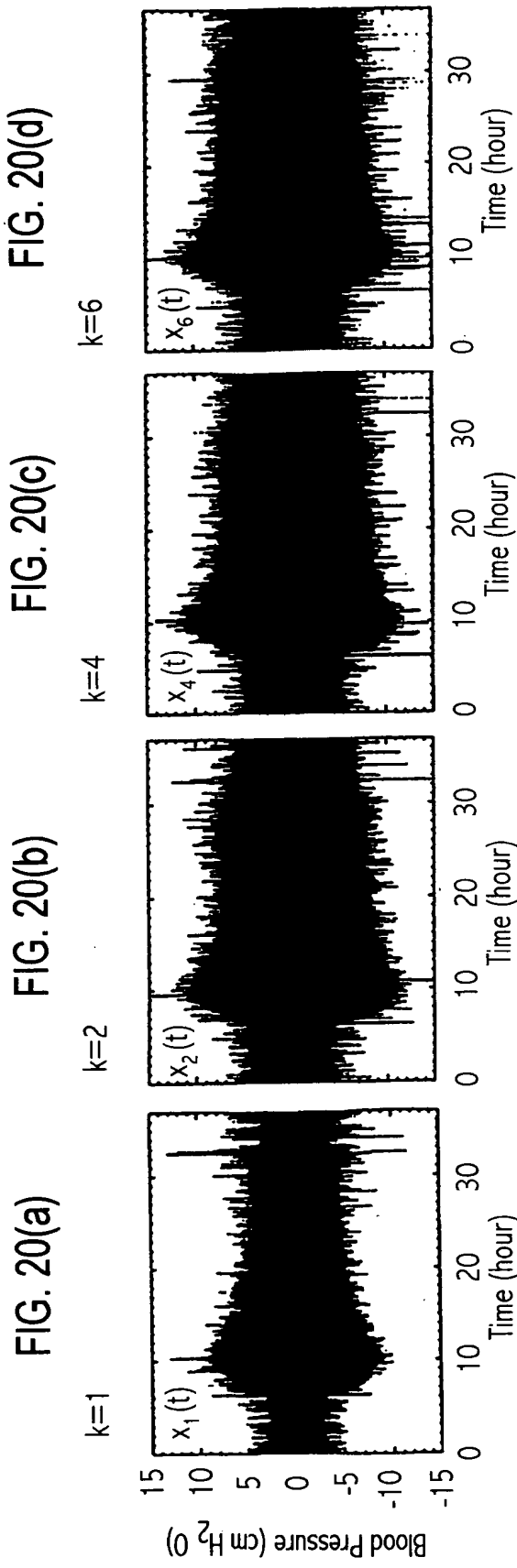
FIG. 20(a) FIG. 20(b) FIG. 20(c) FIG. 20(d)
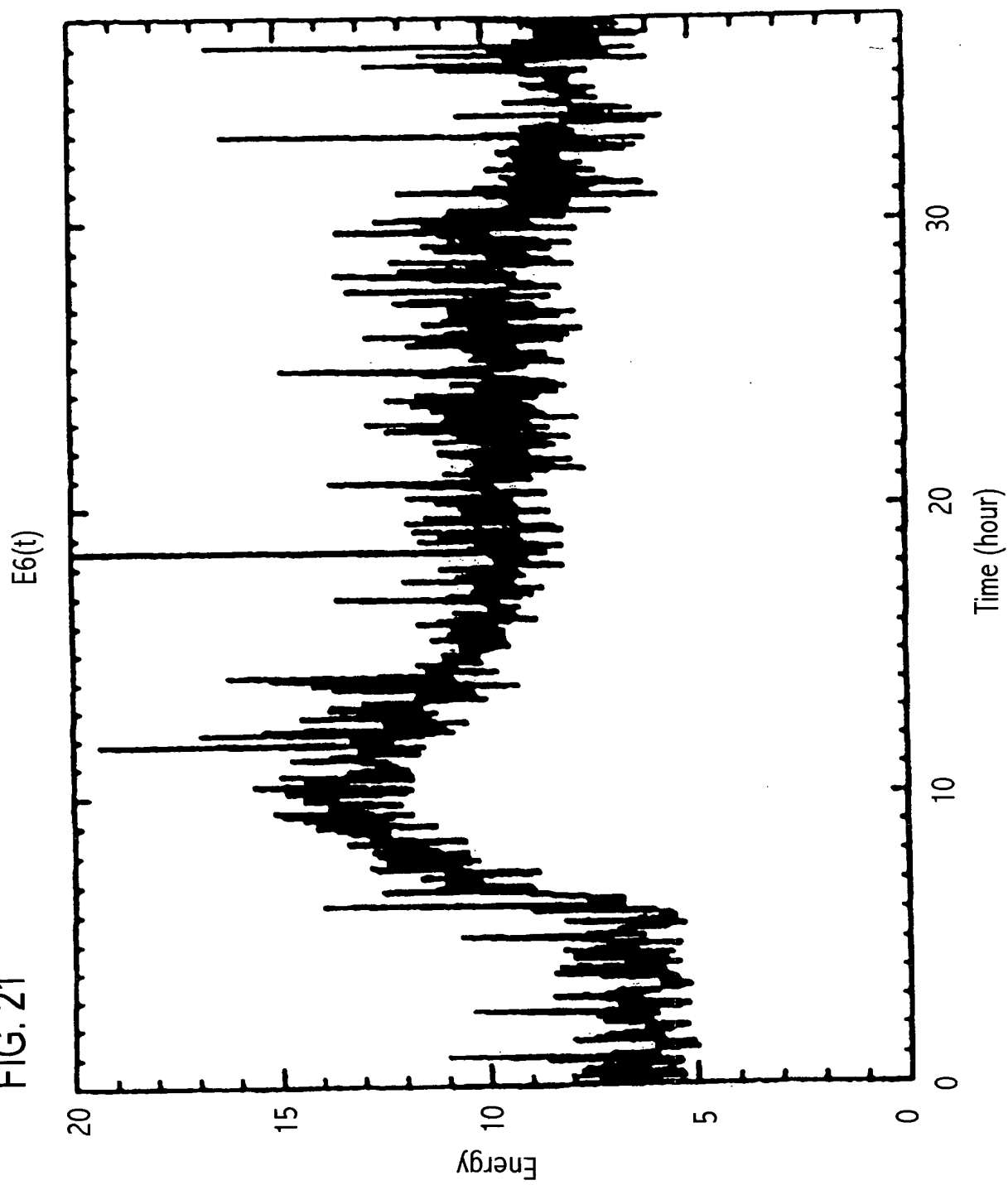
FIG. 21

E6(t)

Energy

Time (hour)

CEK(t): k=9-12

FIG. 22(a)

FIG. 22(b)

FIG. 22(c)

FIG. 22(d)

Time (hour)

CEK(t): k=13-16

FIG. 22(e)

FIG. 22(f)

FIG. 22(g)

FIG. 22(h)

Time (hour)

FIG. 23(a)

Frequency (Hz)

Time (hour)
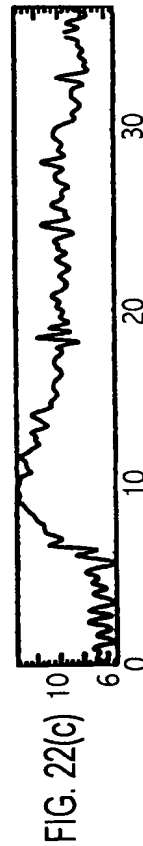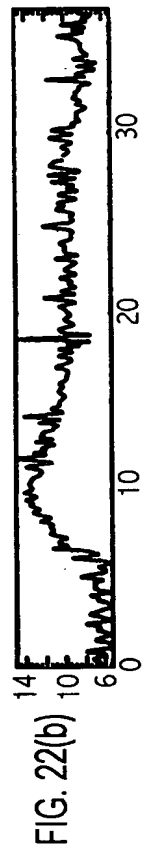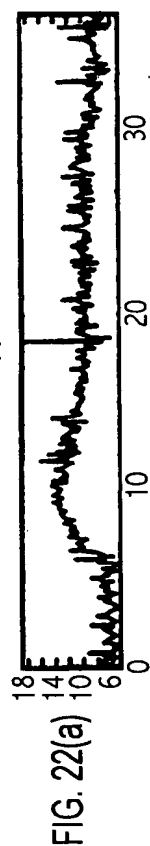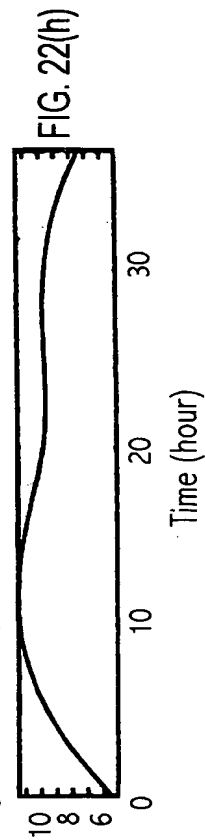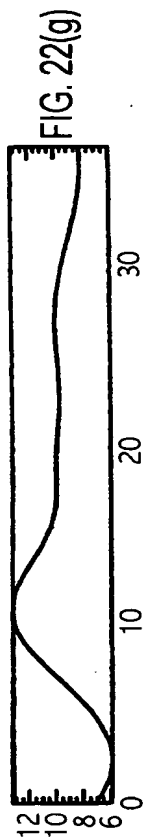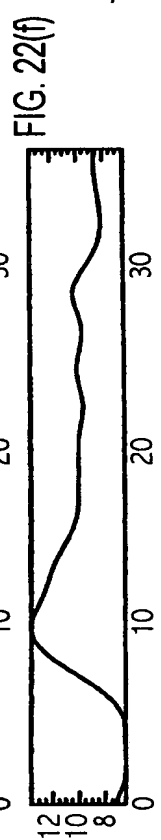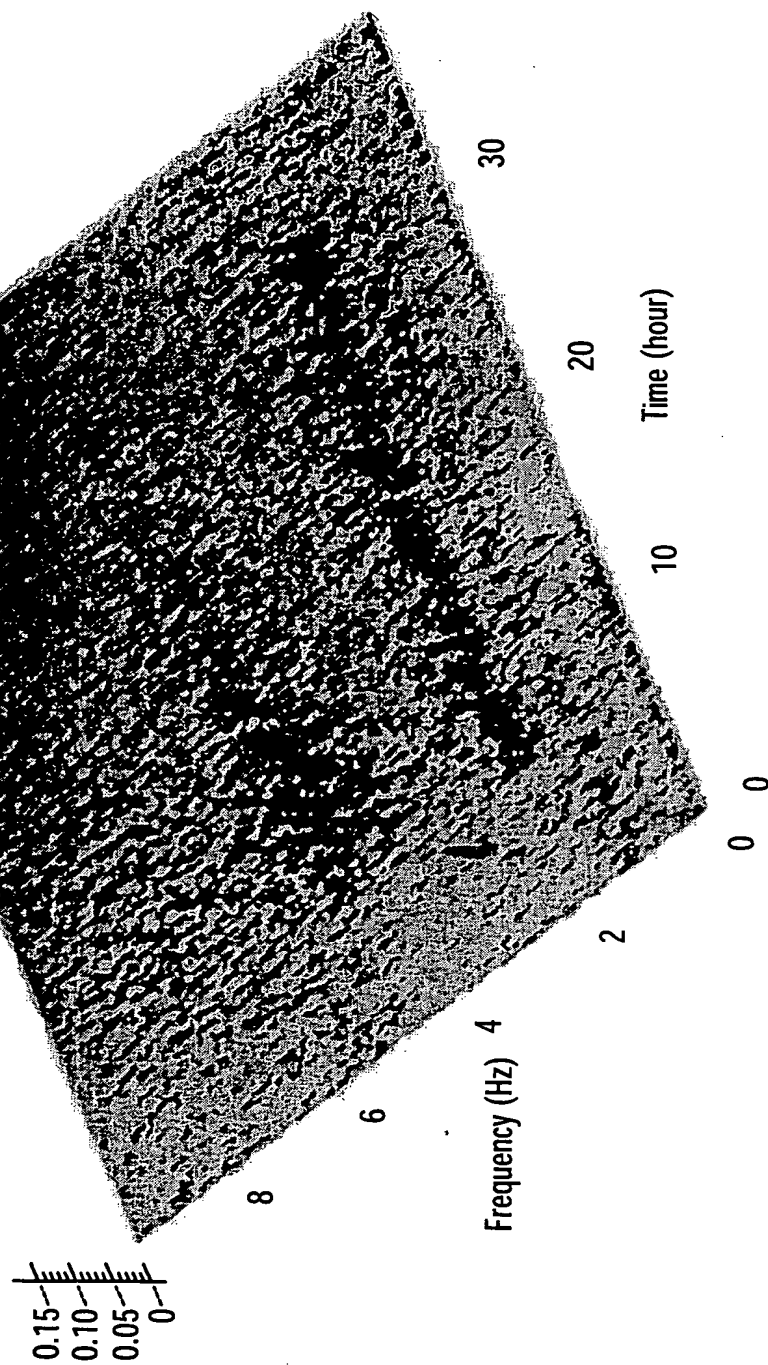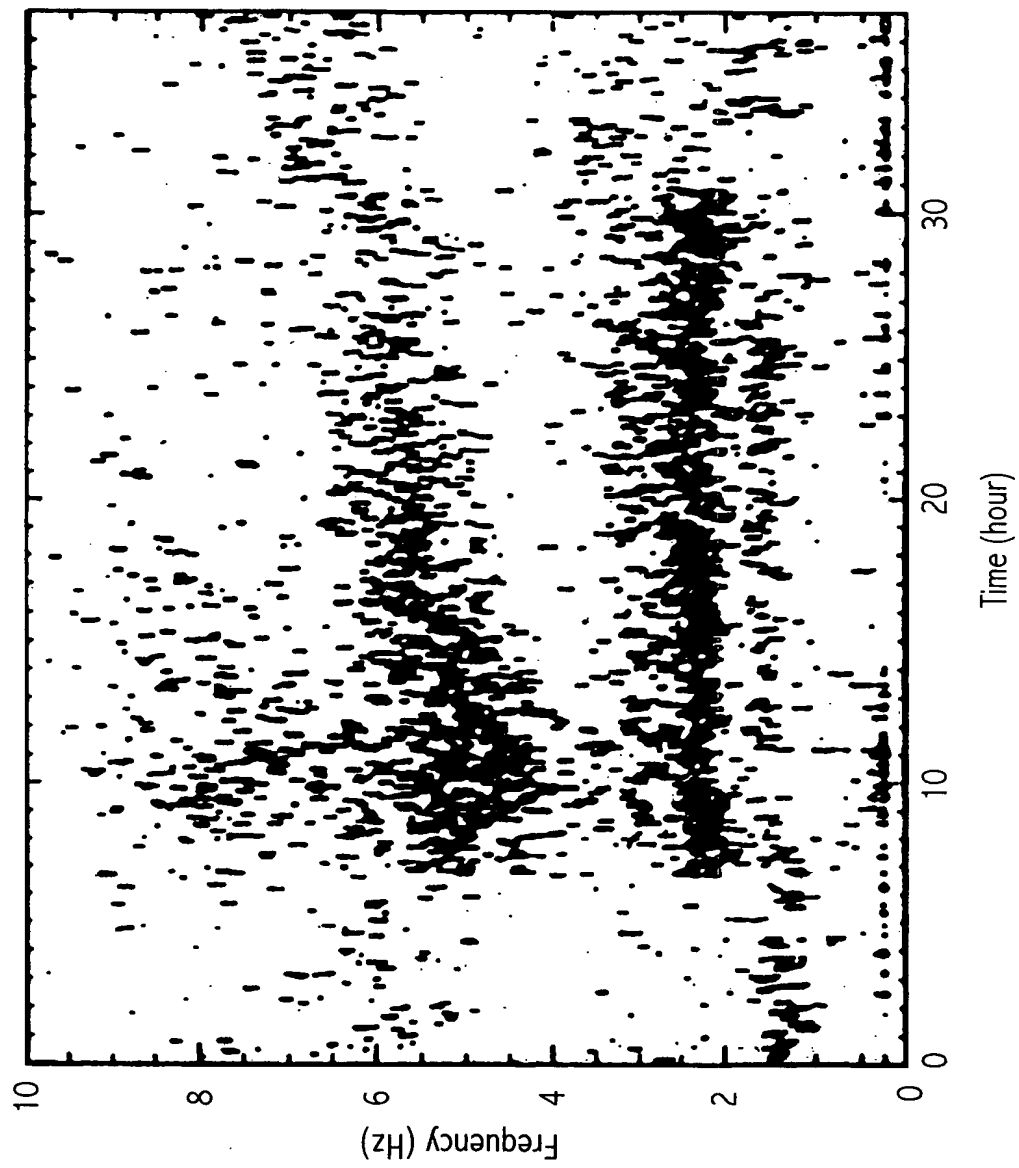
FIG. 23(b)
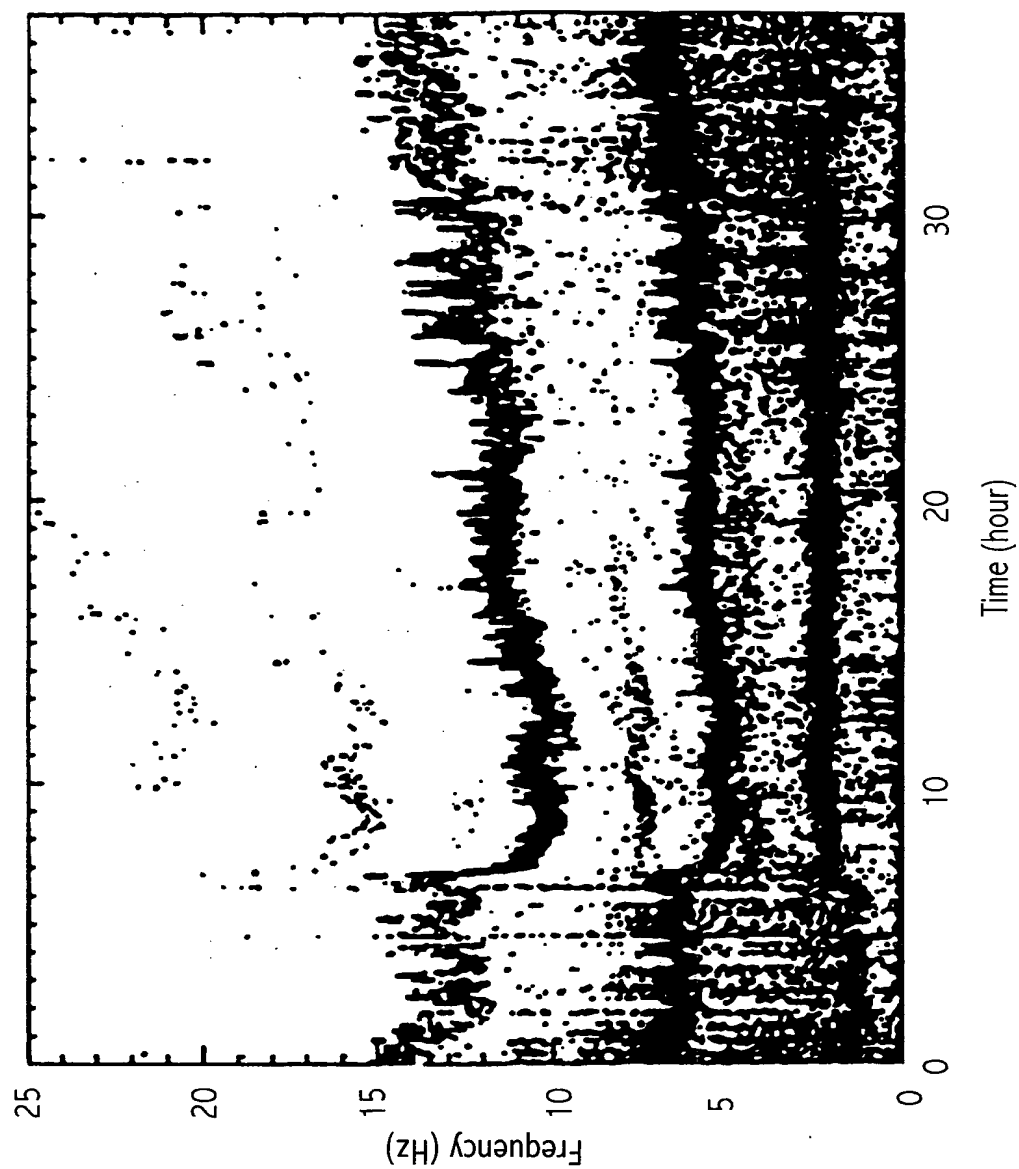
FIG. 24

FIG. 25

Heart Beat Rate Data : nn.slp04

FIG. 26

Heart Beat Rate Data : Normal

IMF Normal

FIG. 27(a)

FIG. 27(b)

FIG. 27(c)

FIG. 27(d)

FIG. 27(e)

FIG. 27(f)

FIG. 27(g)

FIG. 27(h)

Time: second

FIG. 28

Time Series : Normal Section nn.slp04

Pulse Rate: sec

Time: second
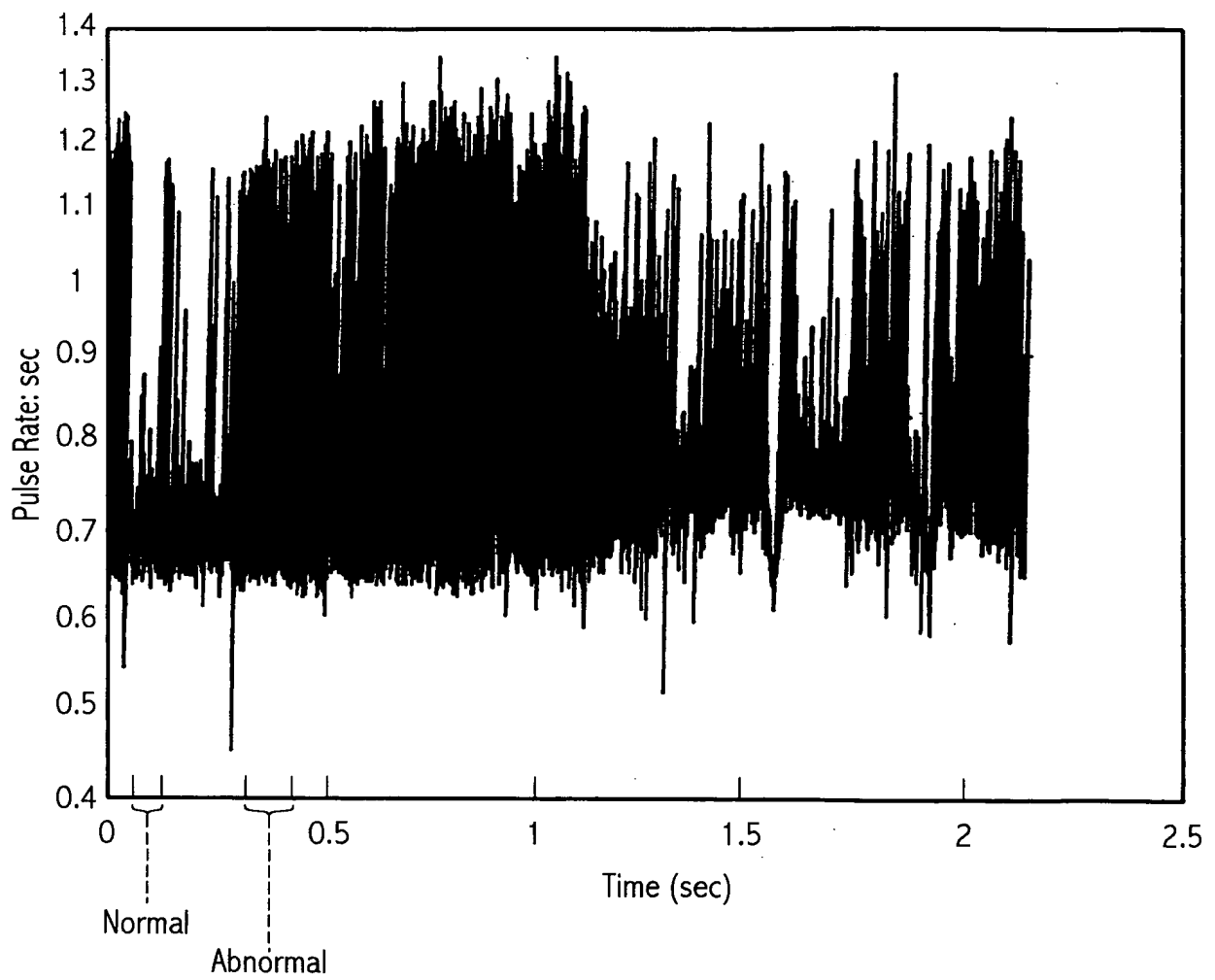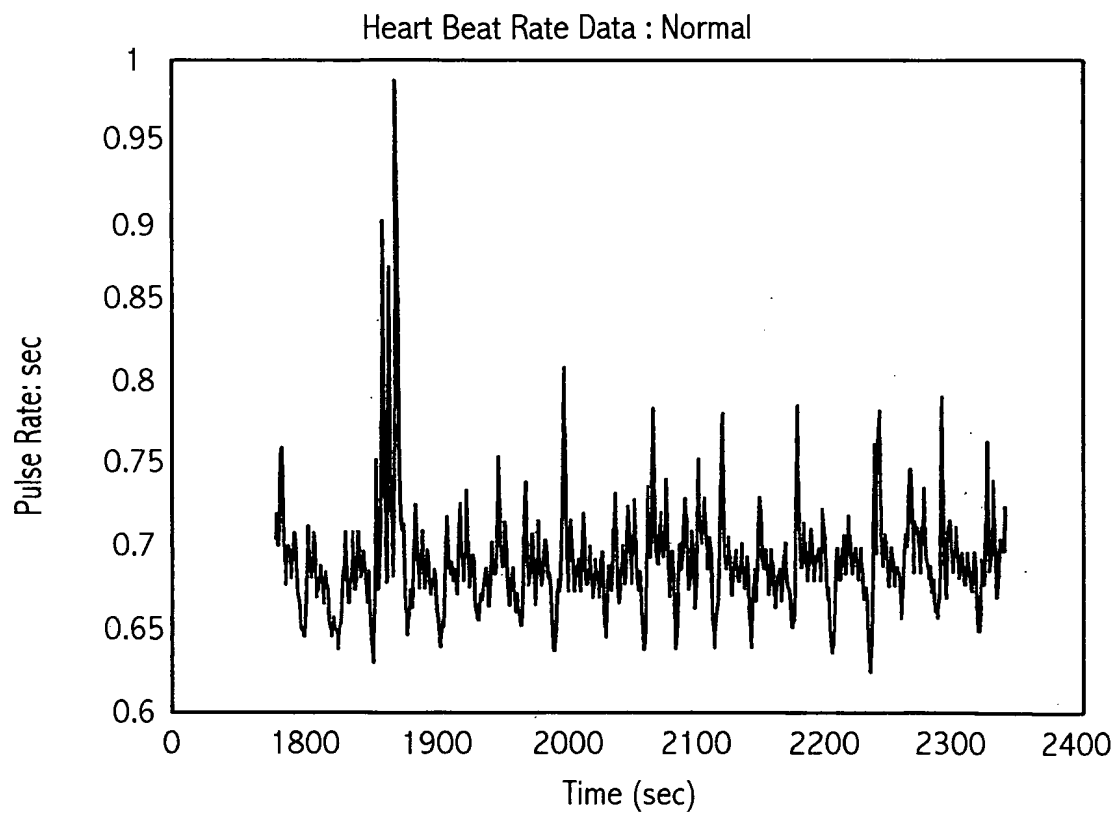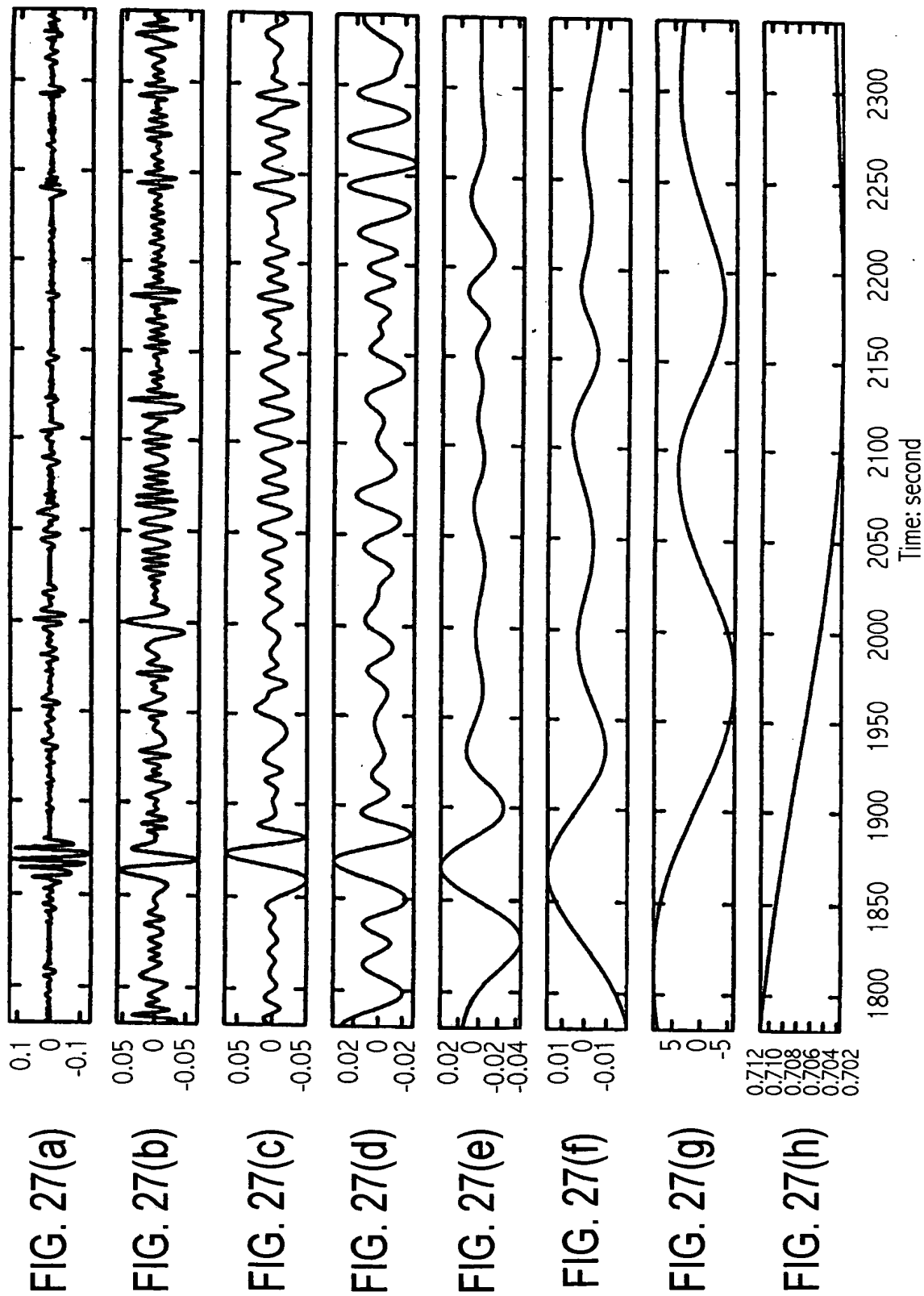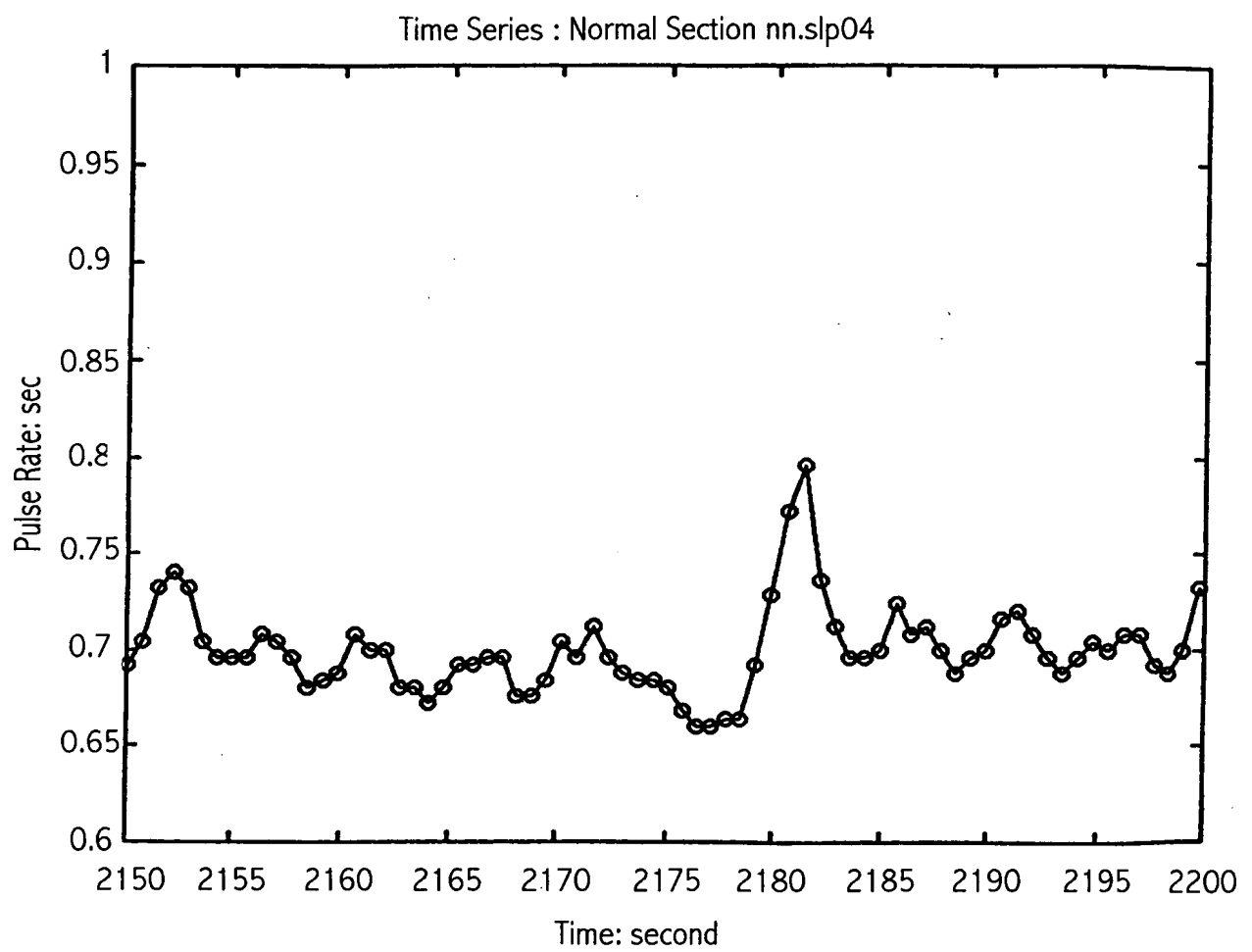
FIG. 29

Hilbert Spectrum : Normal
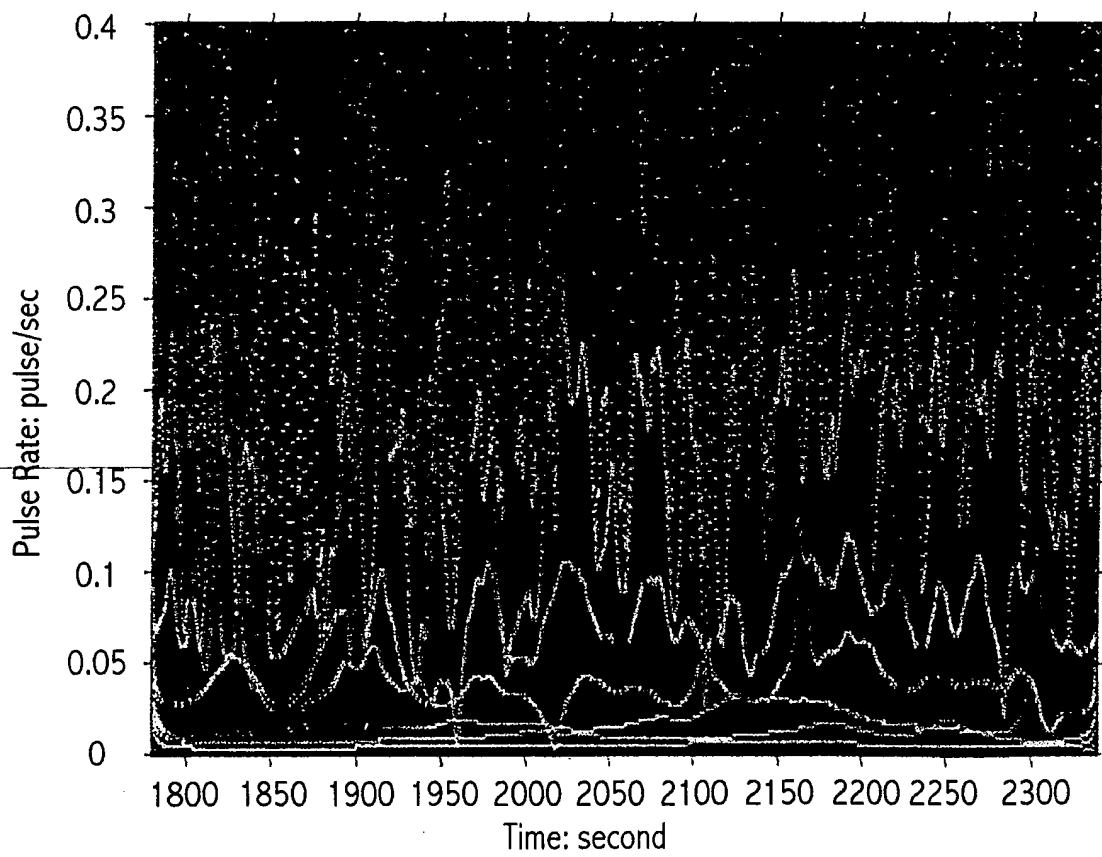
FIG. 30

Heart Beat Rate Data : Abnormal

IMF Abnormal

FIG. 31(a) C1

FIG. 31(b) C2

FIG. 31(c) C3

FIG. 31(d) C4

FIG. 31(e) C5

FIG. 31(f) C6

FIG. 31(g) C7

FIG. 31(h) C8

Time : second
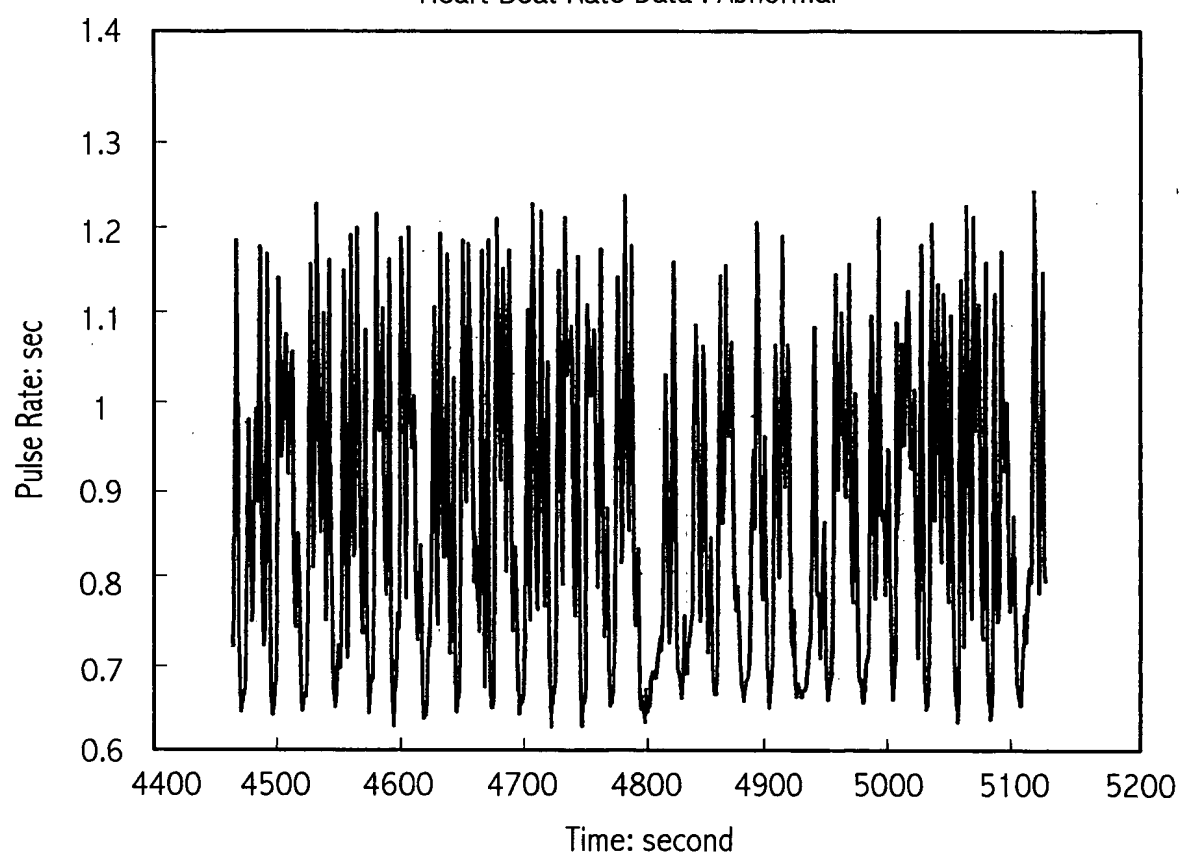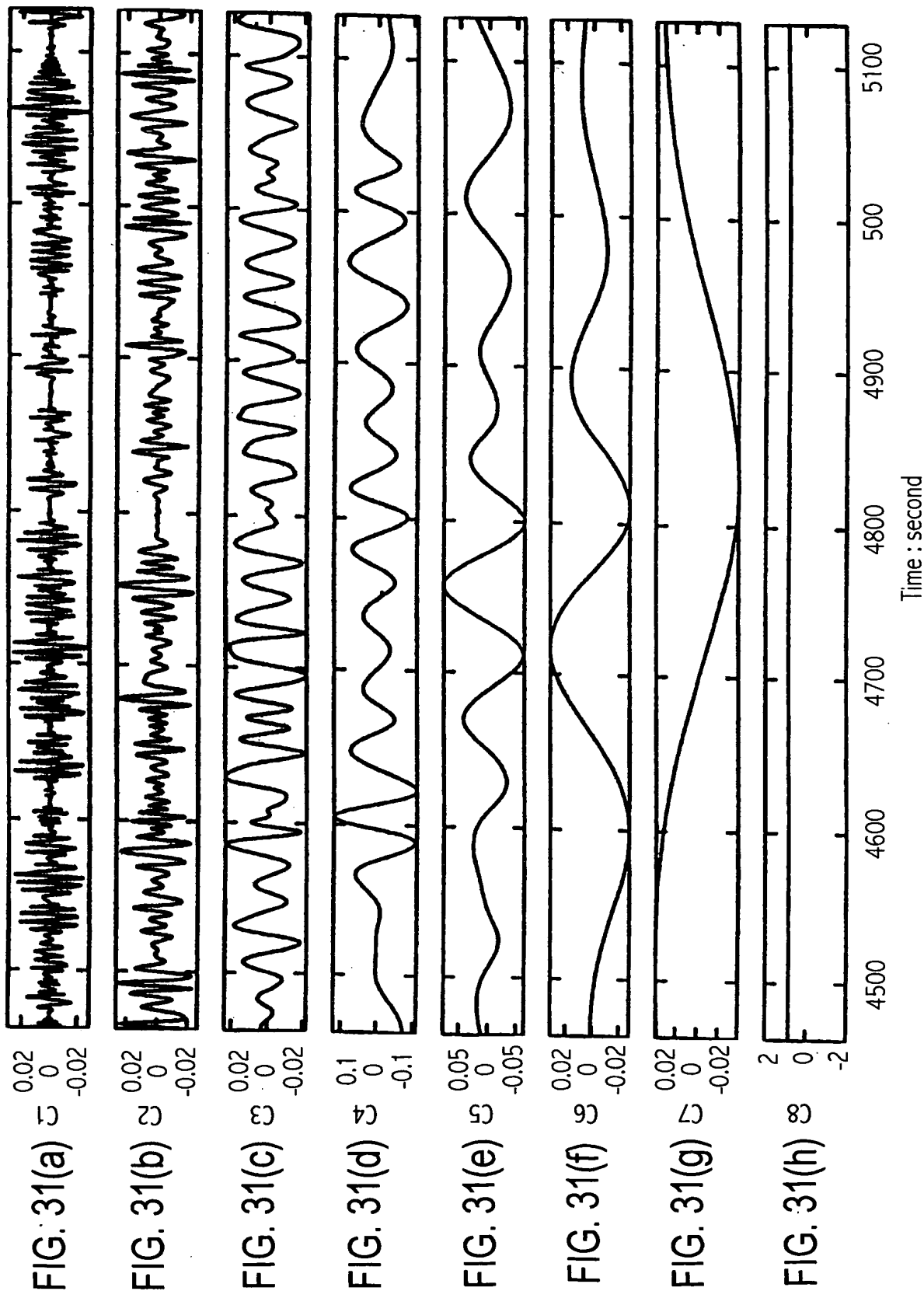
FIG. 32

Time Series : Abnormal Section nn.slp04

FIG. 33

Hilbert Spectrum
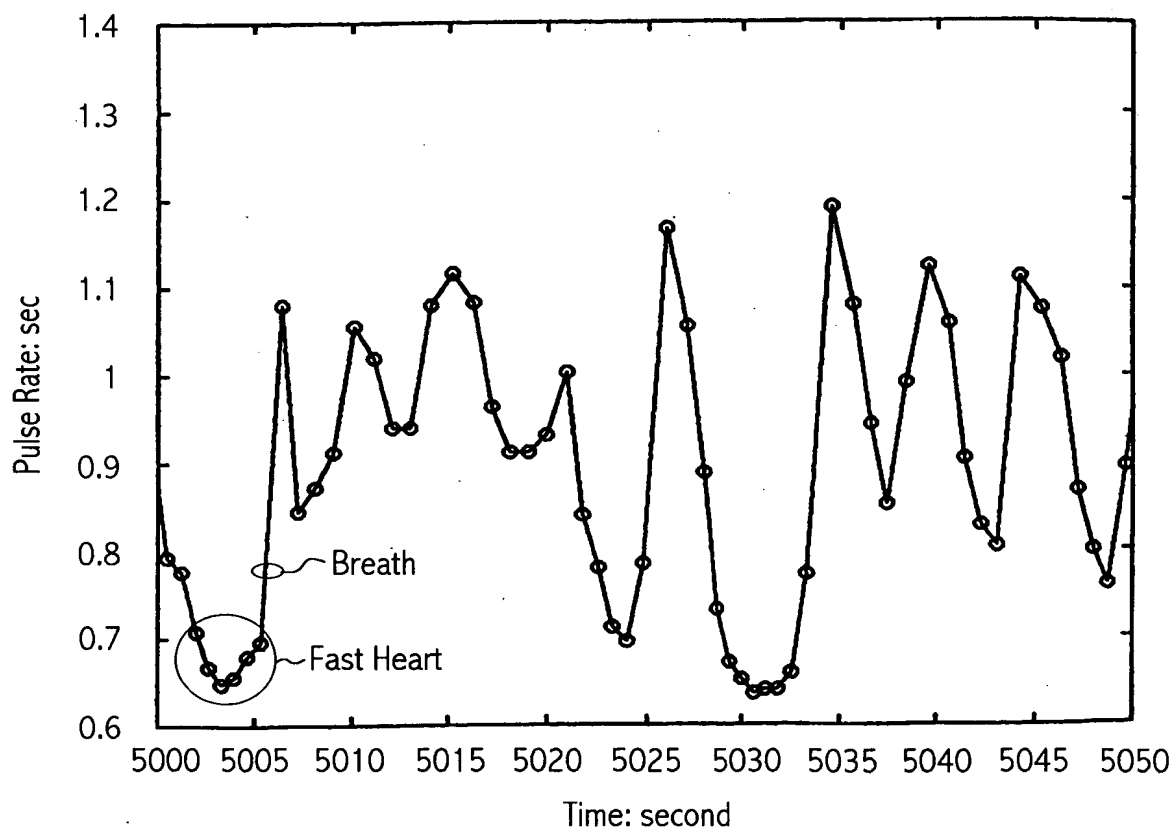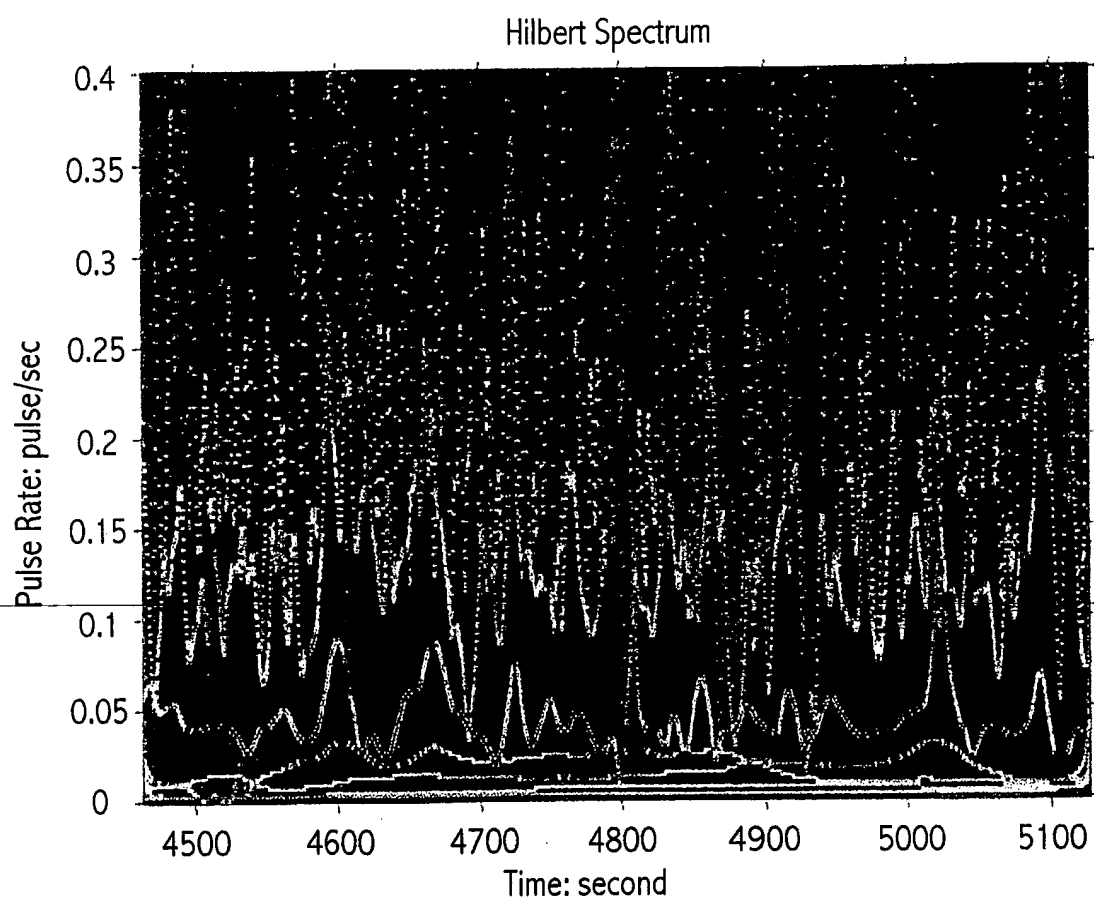
FIG. 34

Seizure Data
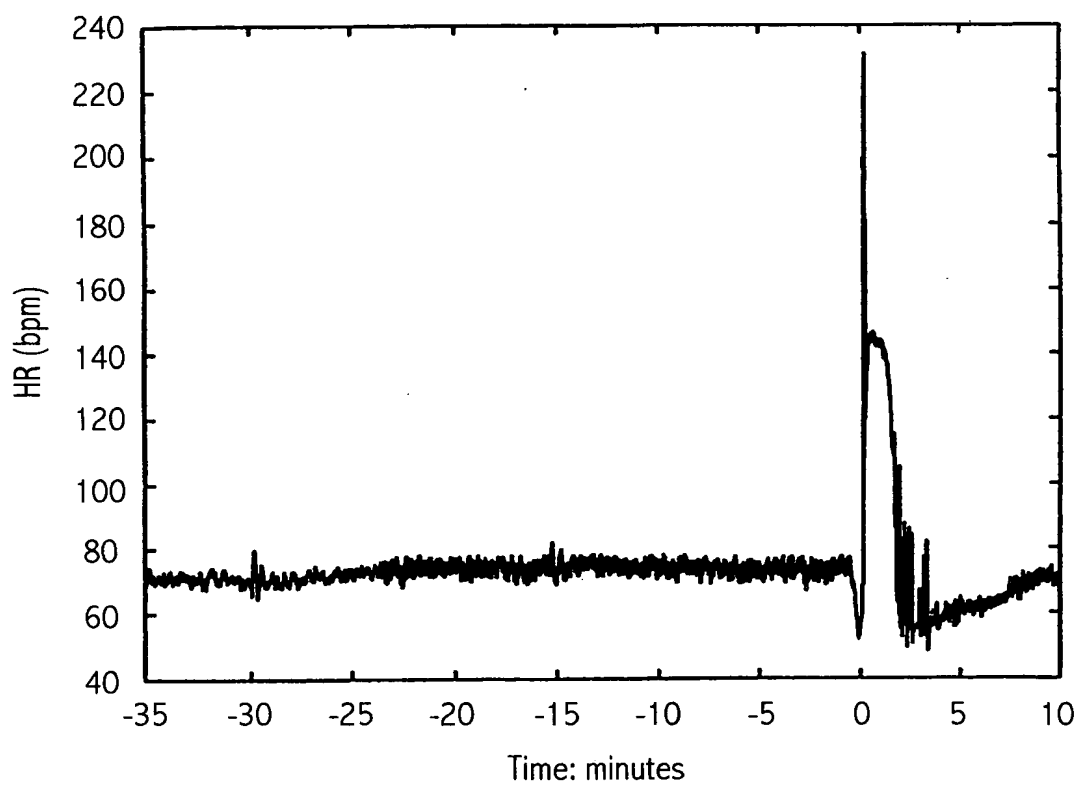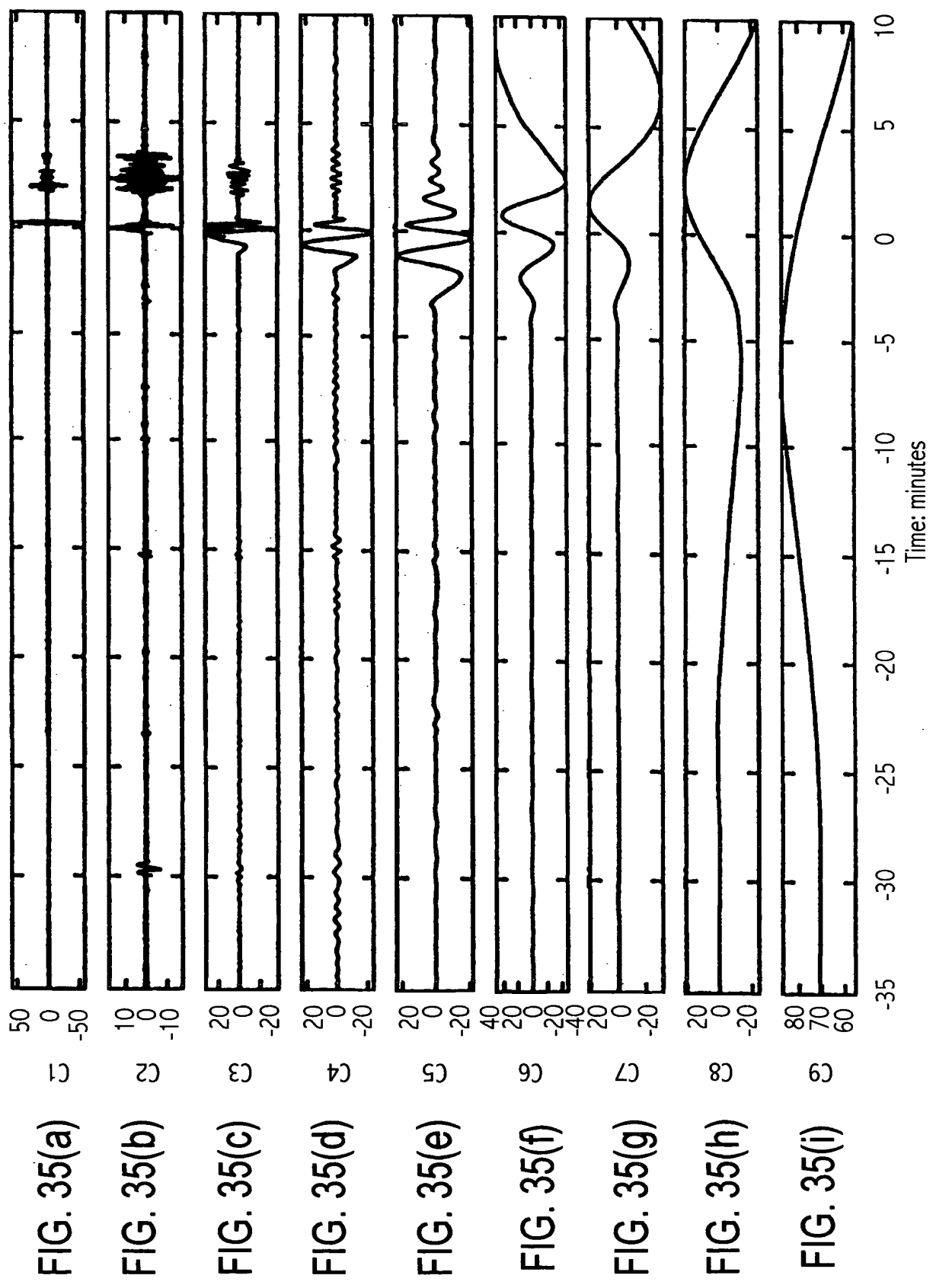
FIG. 35(a)

FIG. 35(b)

FIG. 35(c)

FIG. 35(d)

FIG. 35(e)

FIG. 35(f)

FIG. 35(g)

FIG. 35(h)

FIG. 35(i)

Time: minutes

Intrinsic Mode Decomposition

FIG. 36(a)

Time (minutes)

FIG. 36(b)

Time (minutes)

FIG. 36(c)

Time (minutes)
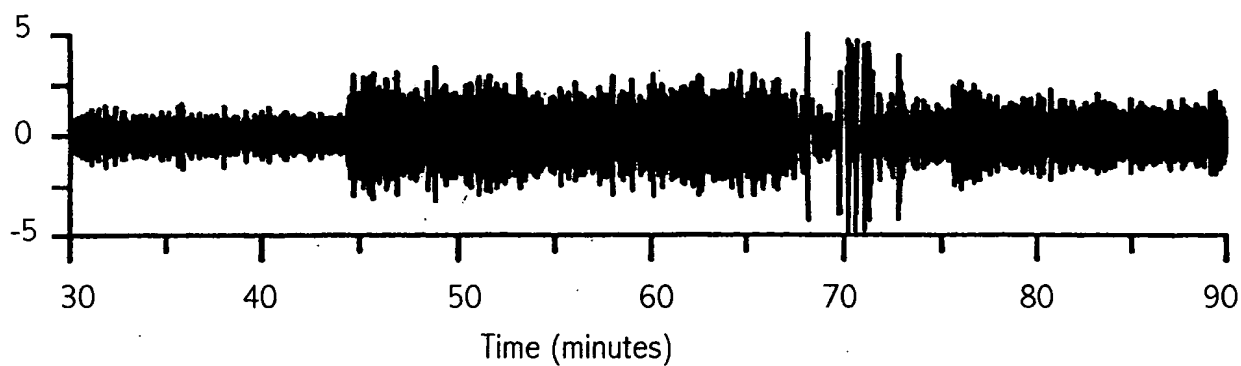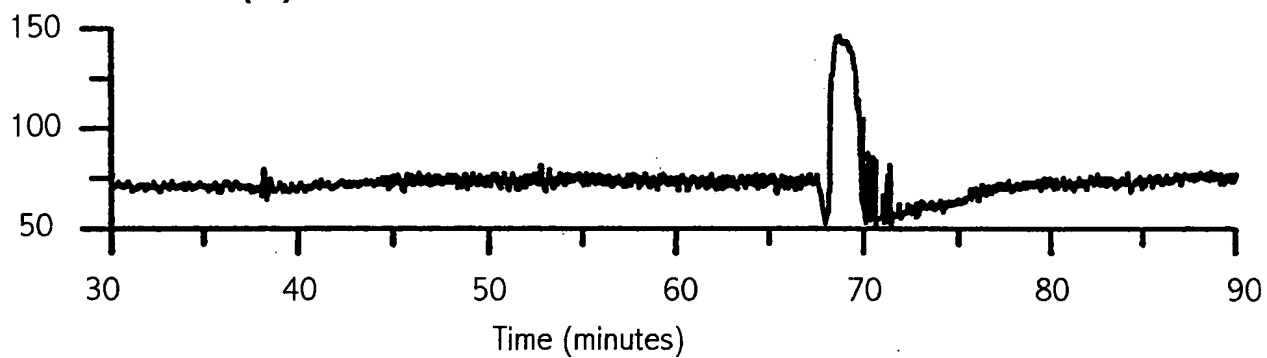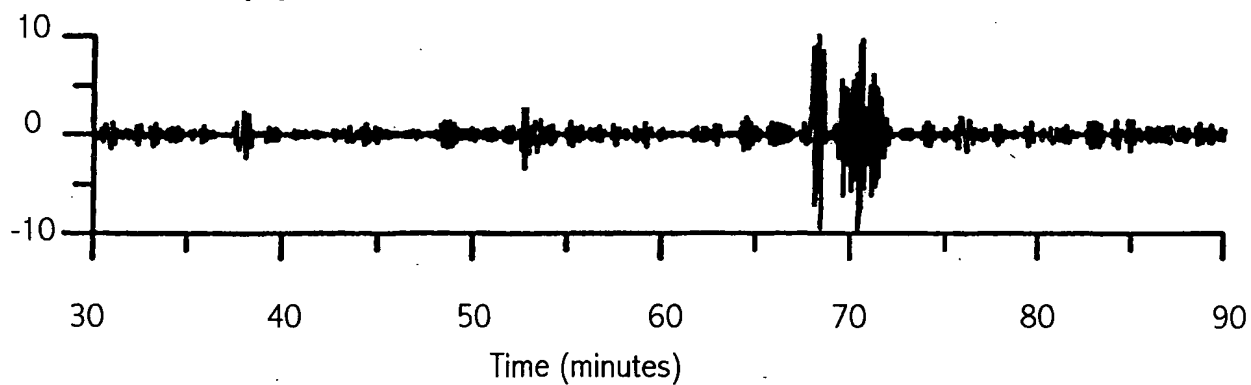
FIG. 37

Hilbert Spectrum Seizure Data

FIG. 38

FIG. 39

TEXT → TEXT Translated into IMFs → Sum IMFs into acoustical signal → Play into speakers

DATABASE OF PHONEMES & FORMANTS (HHT BASED)

FIG. 40

FIG. 41

From a Known Speaker

DATABASE
OF
PHONEMES &
FORMANTS
(HHT BASED)

Speaker A

HHT

Extracting
Phonemes &
Formants

HHT Based
Comparison

Verify the
ID of
Speaker

Speaker B

HHT

Extracting
Phonemes &
Formants

HHT Based
Comparison

A = B
or
A ≠ B

FIG. 42

Established Templates Averaged Over
a large number of speeches

DATABASE
OF
PHONEMES &
FORMANTS
(HHT BASED)

Speech Signal

HHT

Extracting
Phonemes &
Formants

Translate
signal into
Text

Grammar
& Syntax
Check

Verified
Text

Extraxtion of
Key Word for
Action

Issue order

Acoustical Signal

EMD → IMFs & Hilbert Spectrum → Identify Noise in time → Remove Noise IMFs → Synthesize cleaned signal → output

FIG. 43

FIG. 44

FIG. 45(a)

Data : Halloon

FIG. 45(b)

Data : Hallooj

Time : second

FIG. 46(a)

IMF : Halloon

FIG. 46(b)

IMF : Hallooj

FIG. 47(a)

Hilbert Spectrum : Halloon

Frequency : Hz

Time : second

FIG. 47(b)

Hilbert Spectrum : Hallooj

FIG. 48(a)

Fourier Spectrogram (1024): Halloon

FIG. 48(b)

Fourier Spectrogram (1024): Hallooj

FIG. 49(a)

Detailed Hilbert Spectrum : Halloon

FIG. 49(b)

Detailed Hilbert Spectrum : Hallooj

FIG. 50

Fourier Spectrogram (128) : Halloon

FIG. 51(a)

Detailed Fourier Spectrogram : Halloon
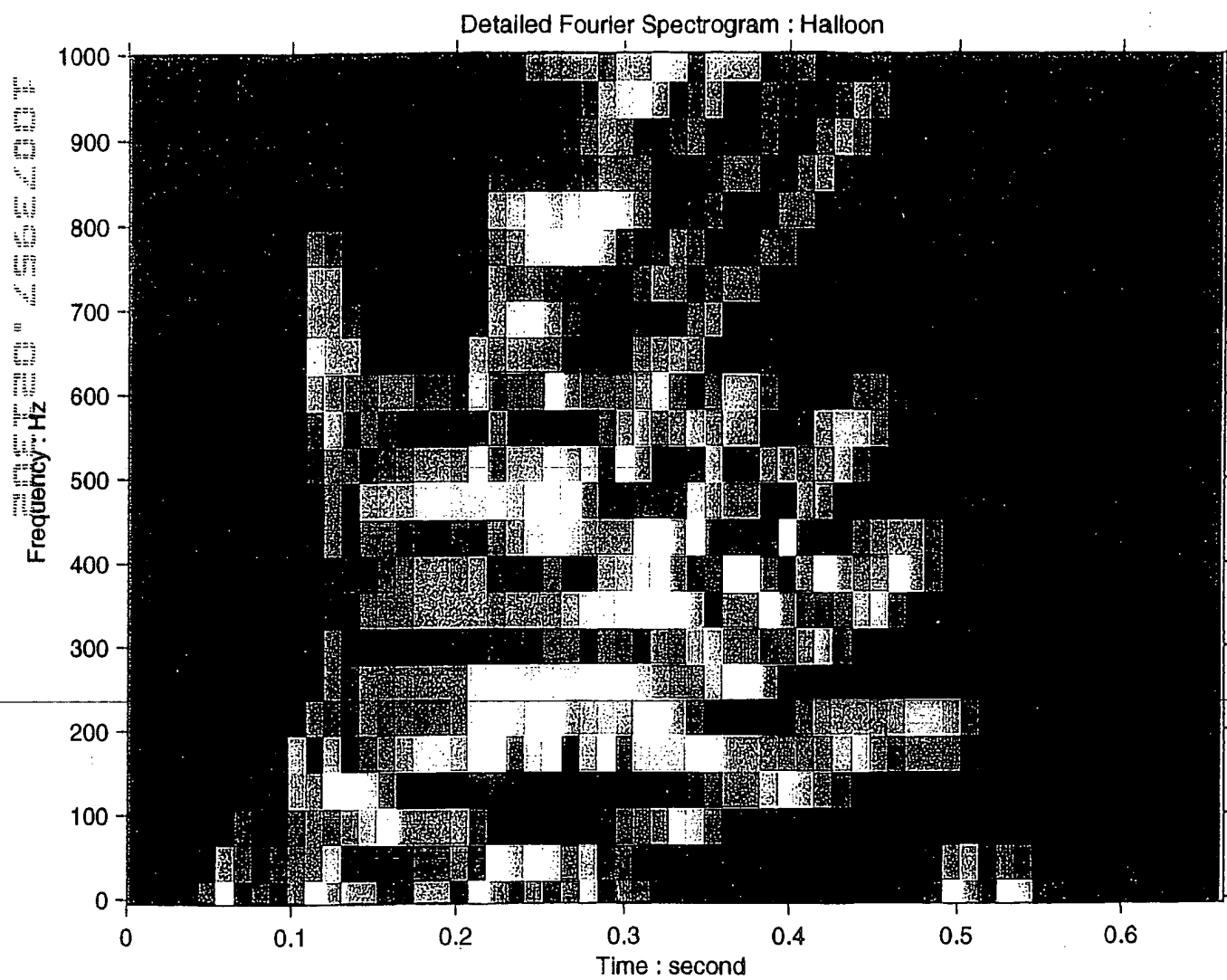
FIG. 51(b)

Detailed Fourier Spectrogram (128) : Halloon

Frequency : Hz

Time : second
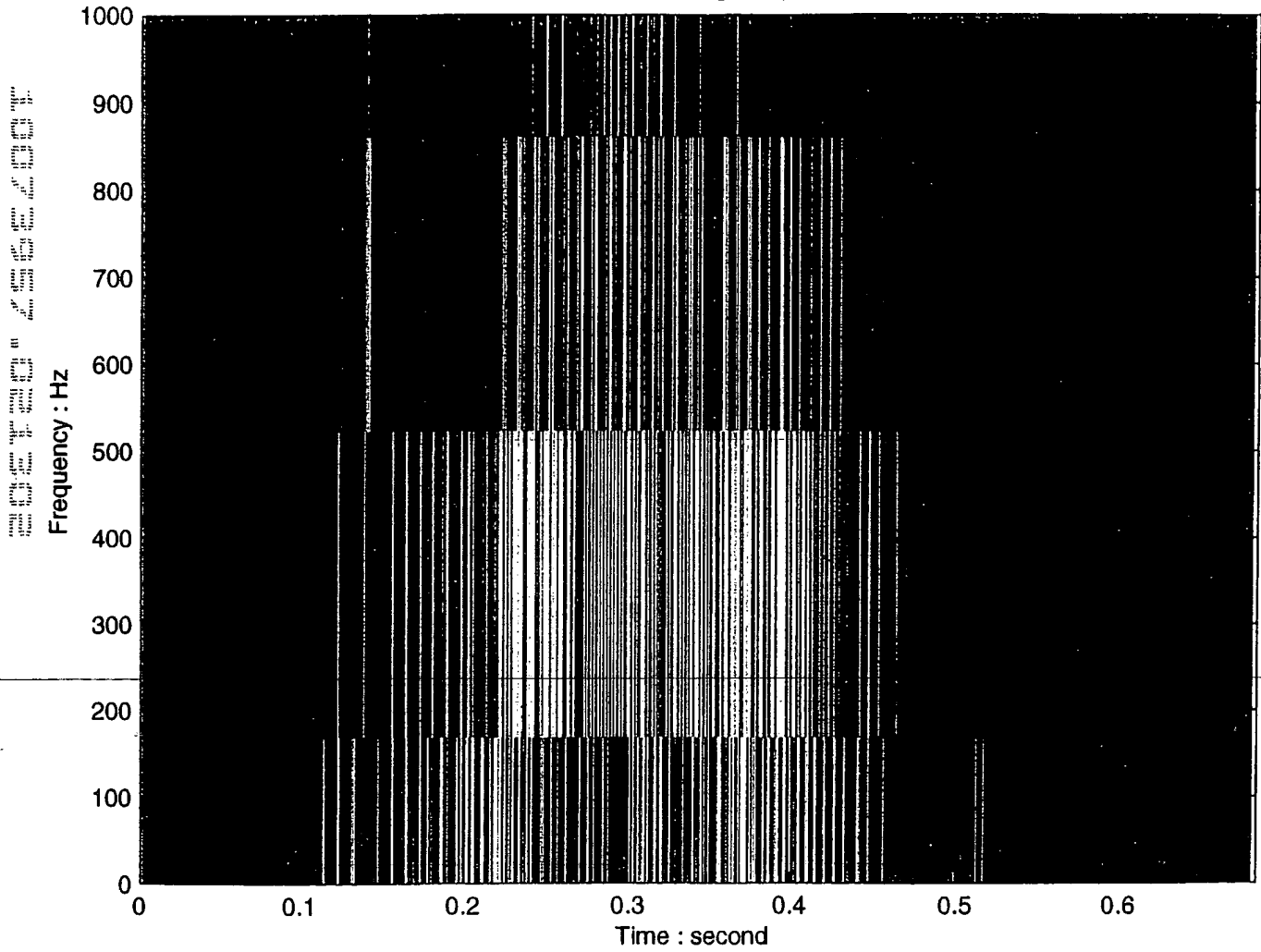
FIG. 52(a)

Detailed Morlet Wavelet Spectrum : Halloon

Frequency : Hz

Time : second

FIG. 52(b)

Detailed Morlet Wavelet Spectrum : Hallooj

FIG. 53(a)

Detailed Hilbert Spectrum : Halloonx100

FIG. 53(b)

Detailed Hilbert Spectrum : Halloonx200

FIG. 54(a)

Detailed Hilbert Spectrum and Data : Halloon

FIG. 54(b)

Detailed Hilbert Spectrum and Data : Halloon

FIG. 55

Data : Halloo+Ding, Halloo, and Ding
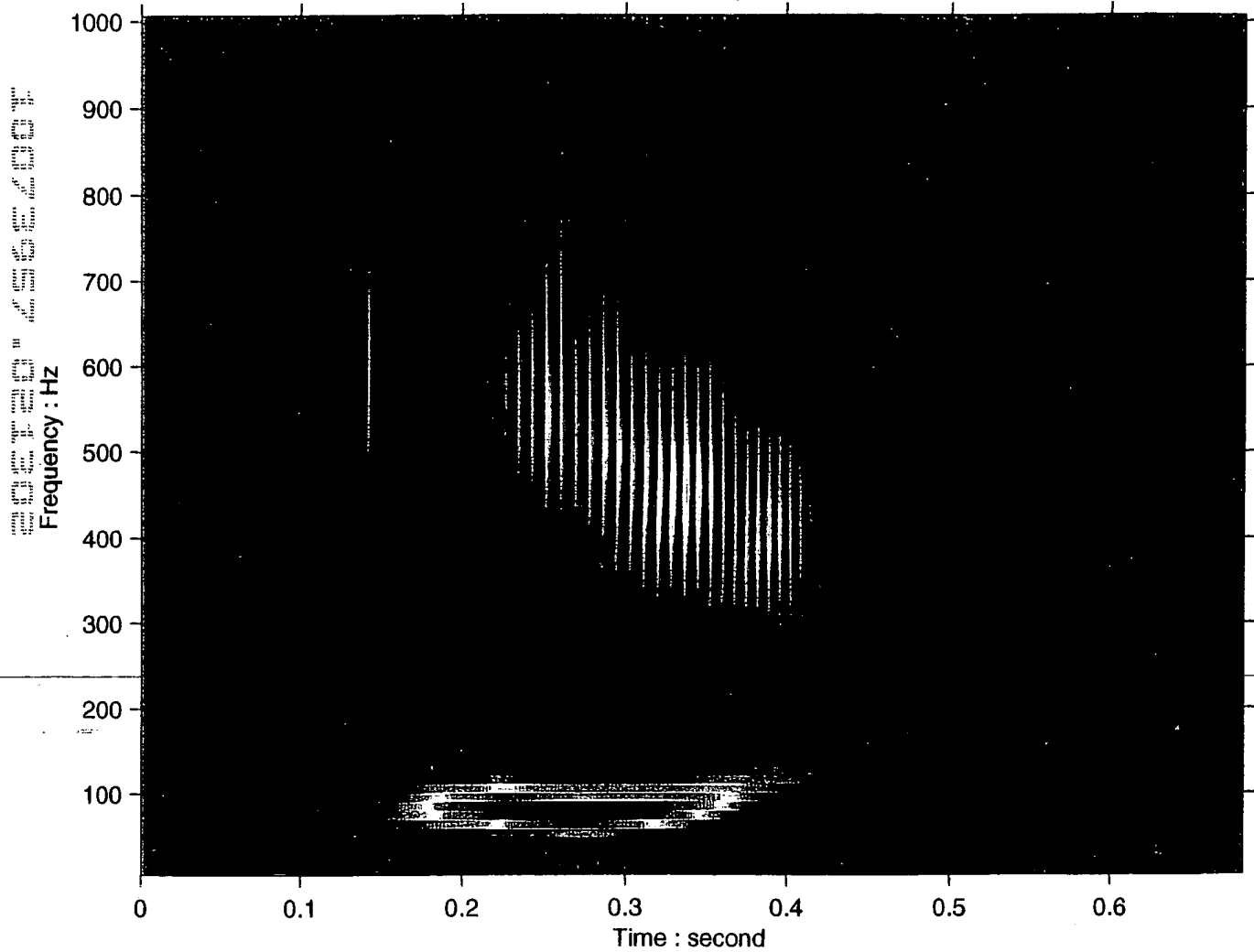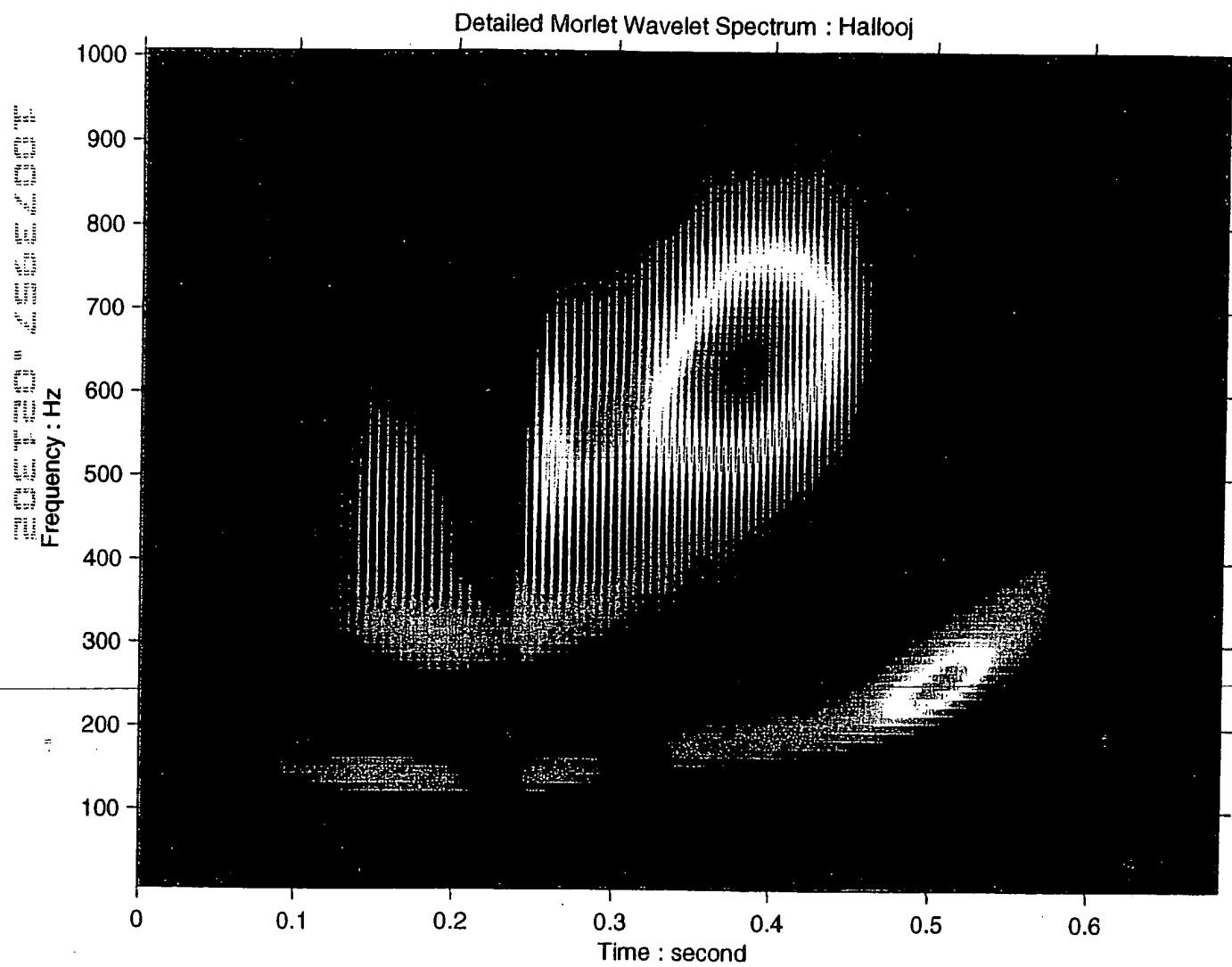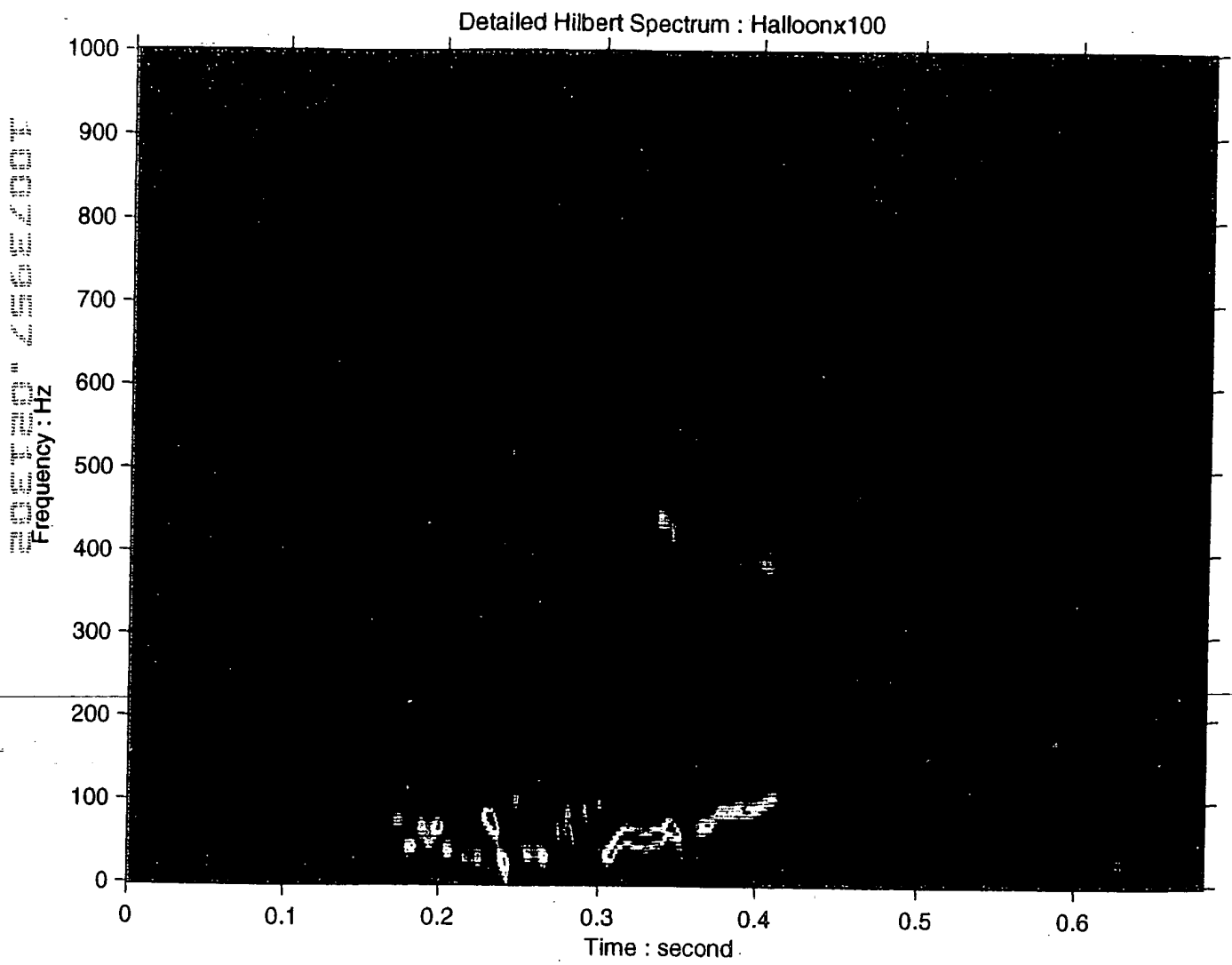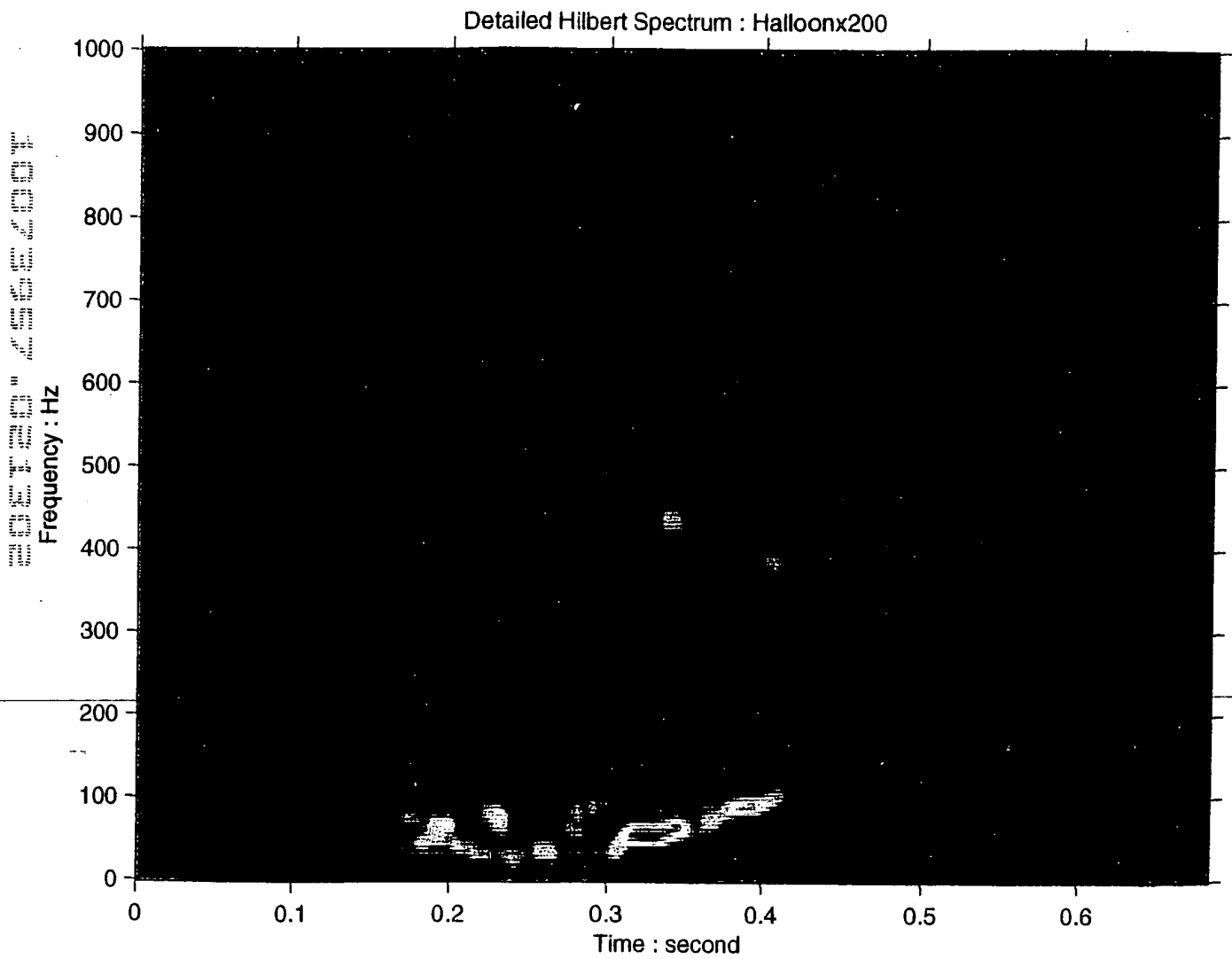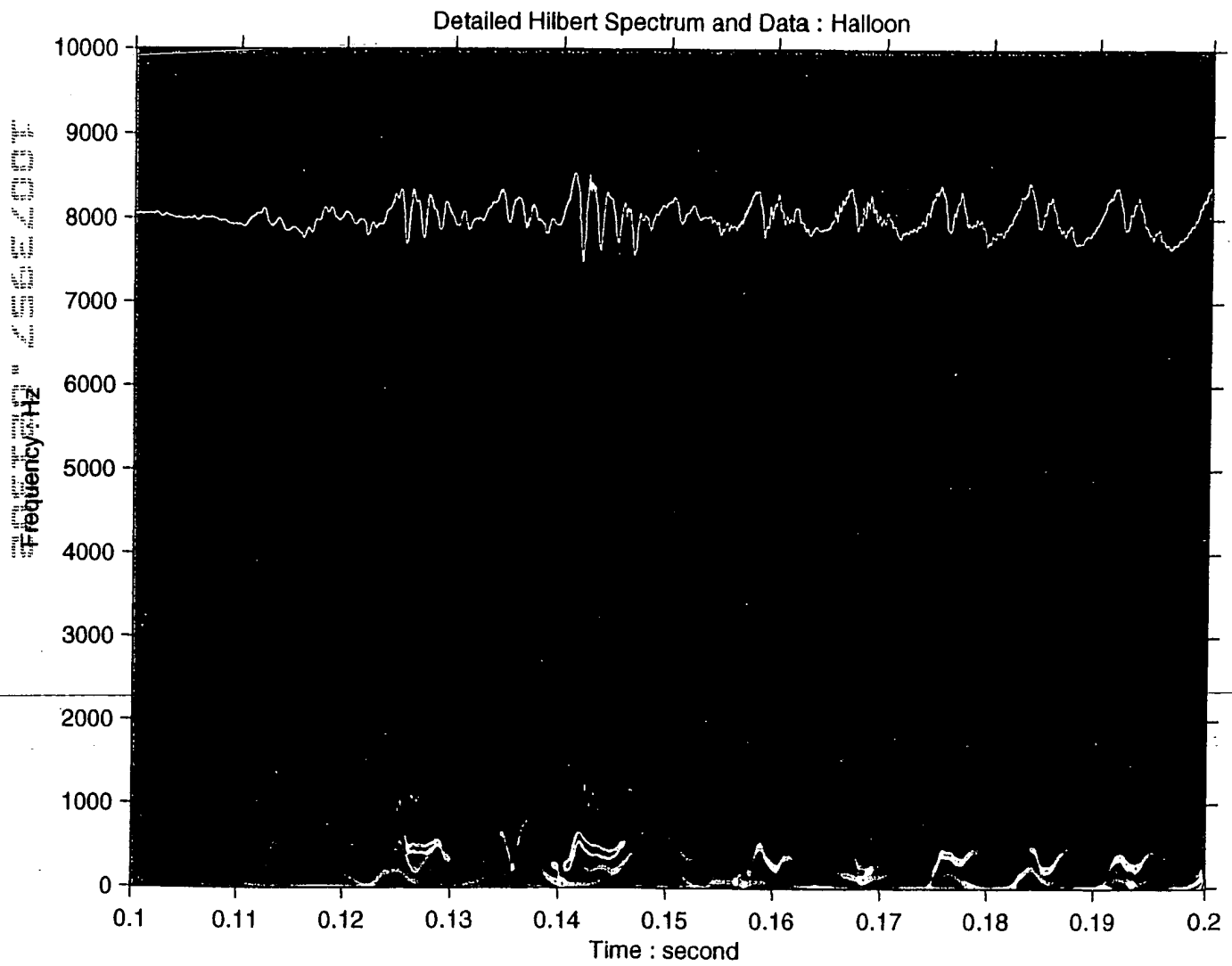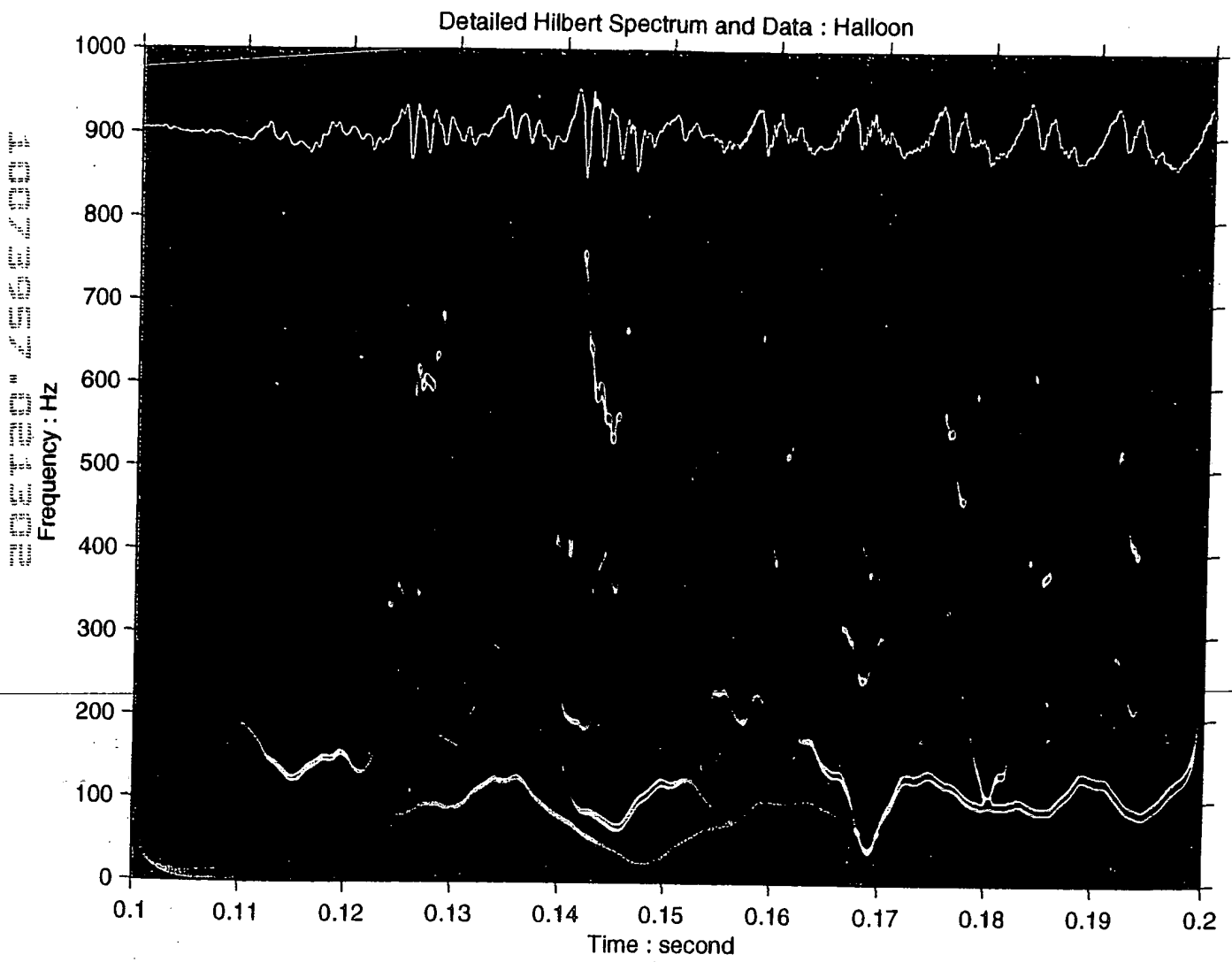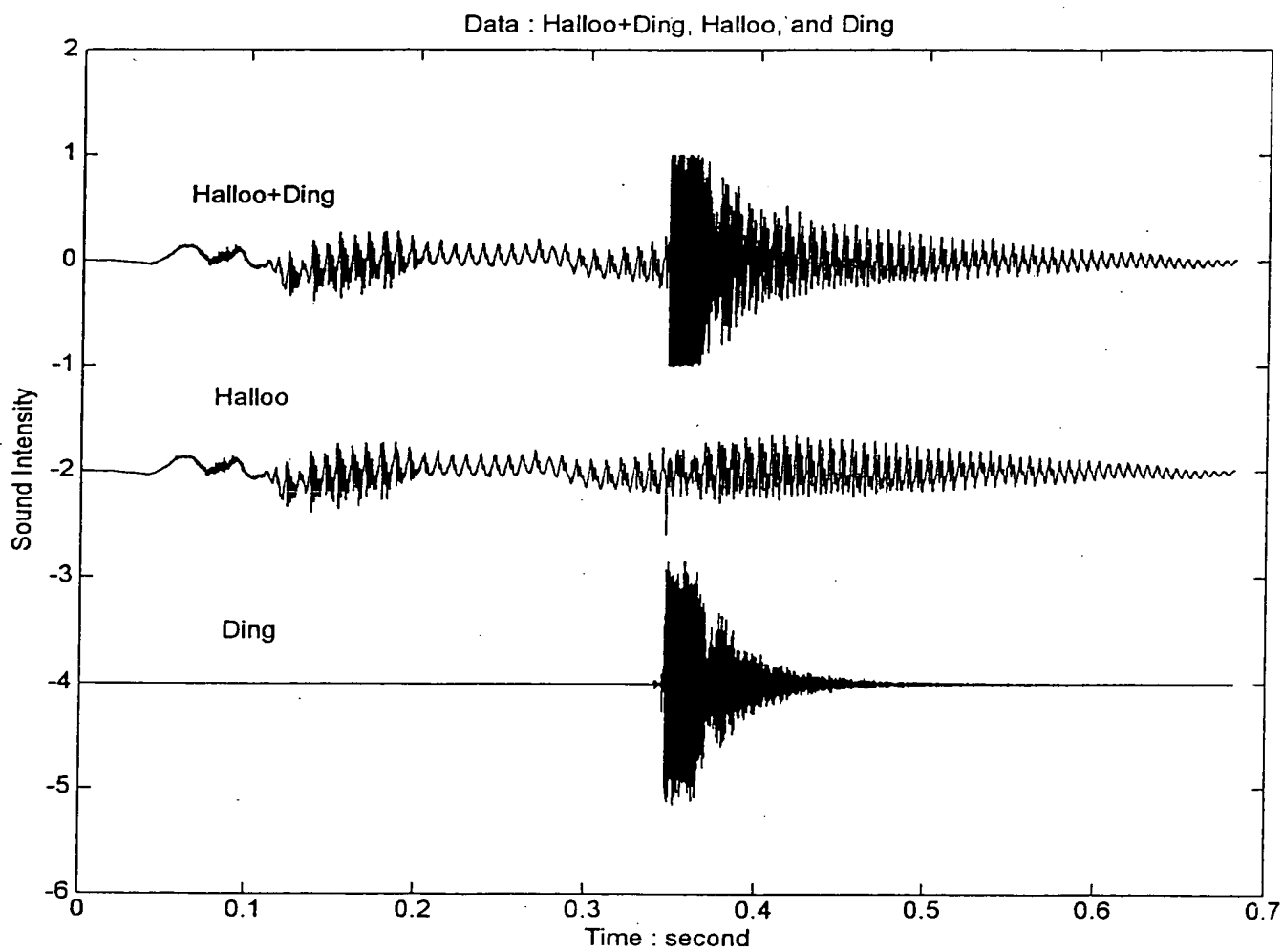
FIG. 56(a)
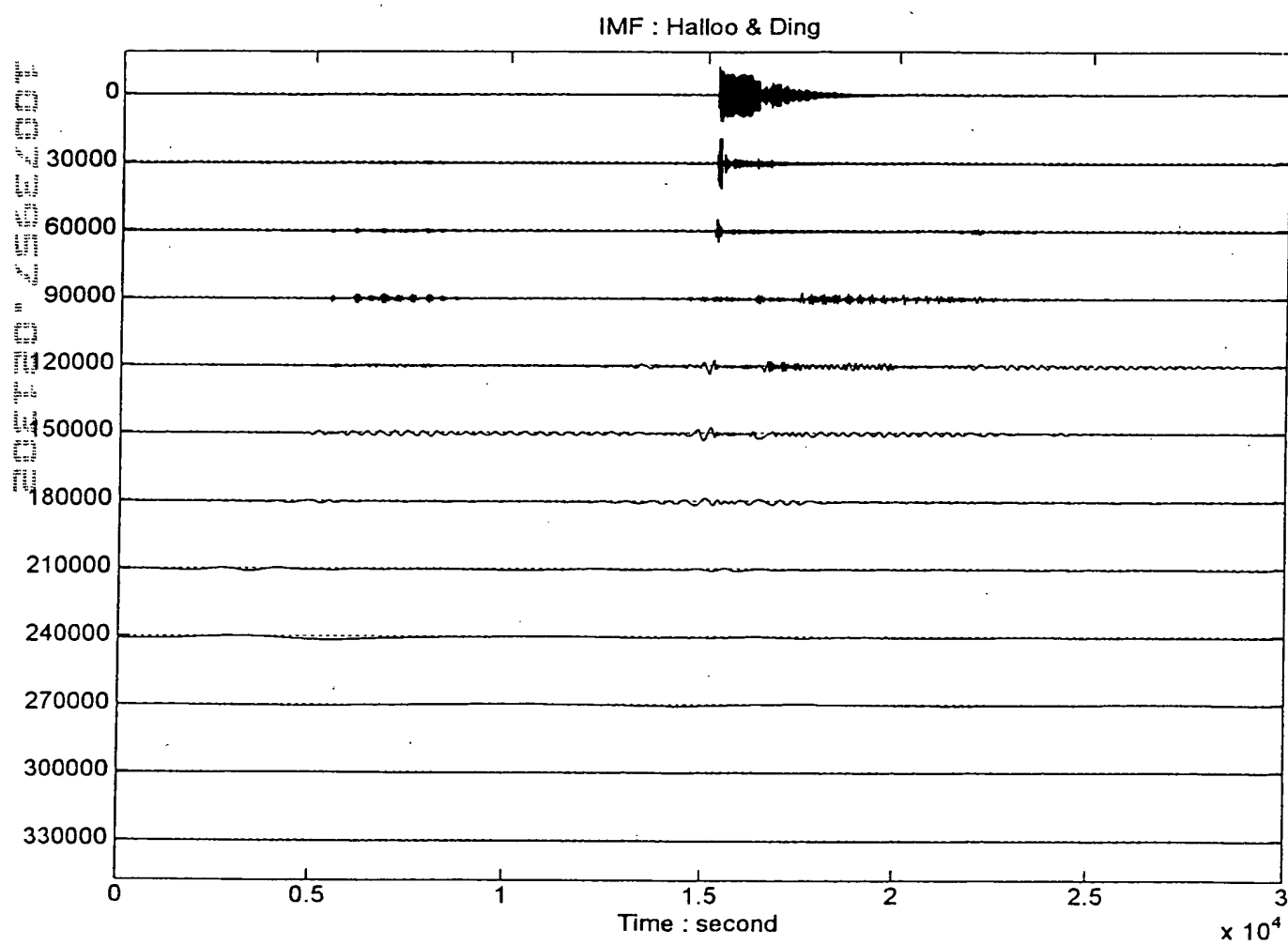
IMF : Halloo & Ding

FIG. 56(b)
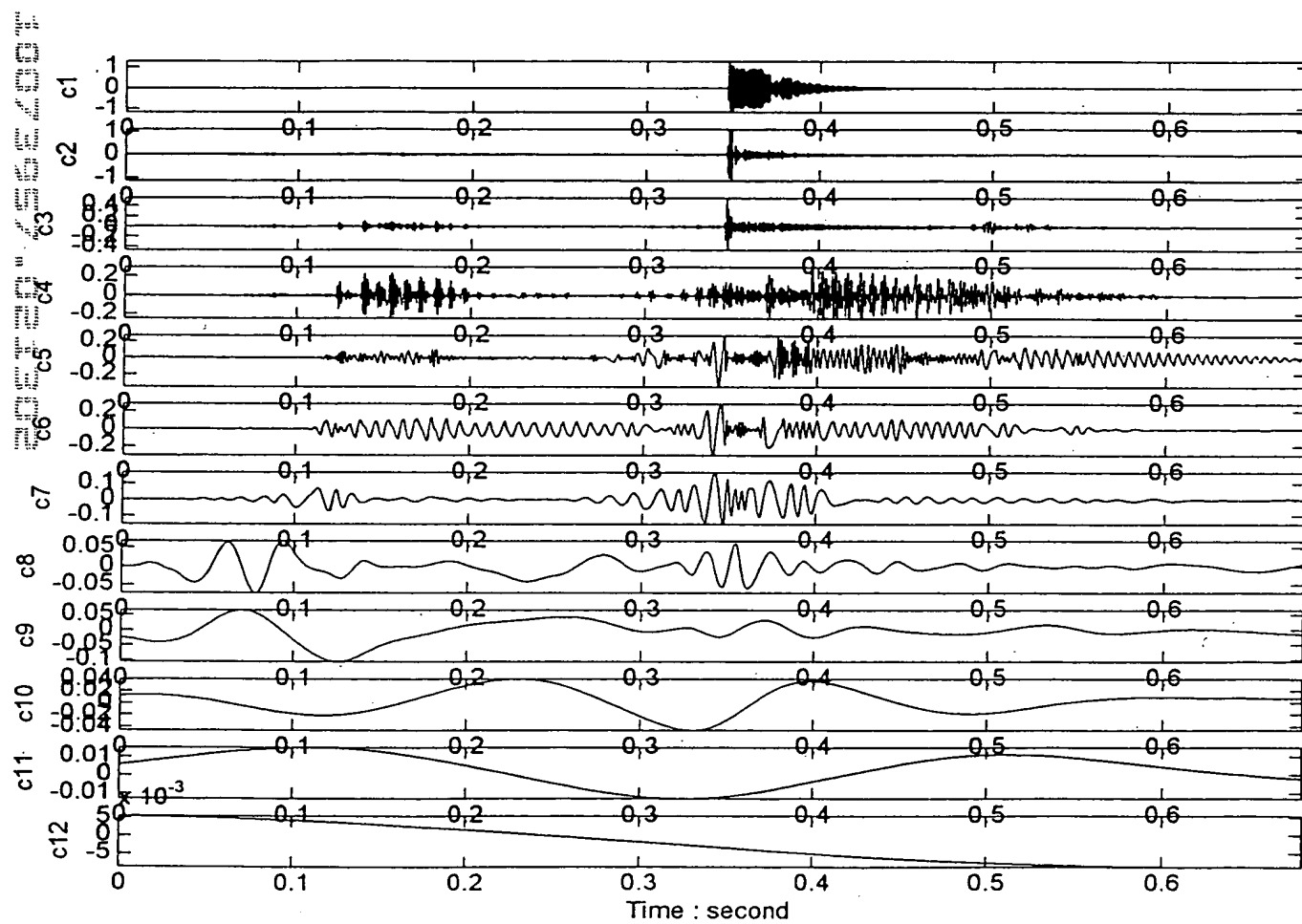
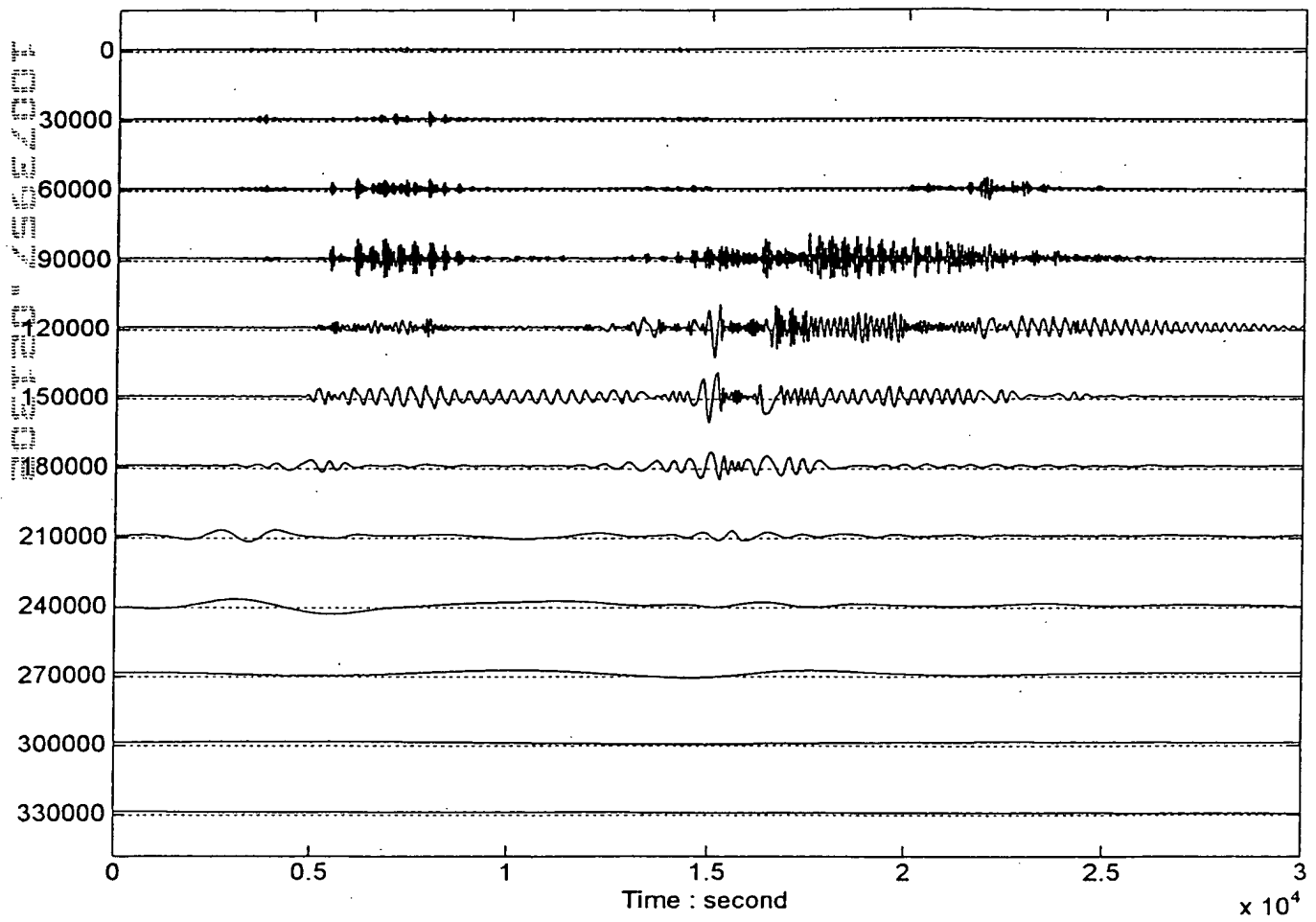IMF : Halloo & Ding

FIG. 57(a)

IMF : Filtered Halloo & Ding

Time : second
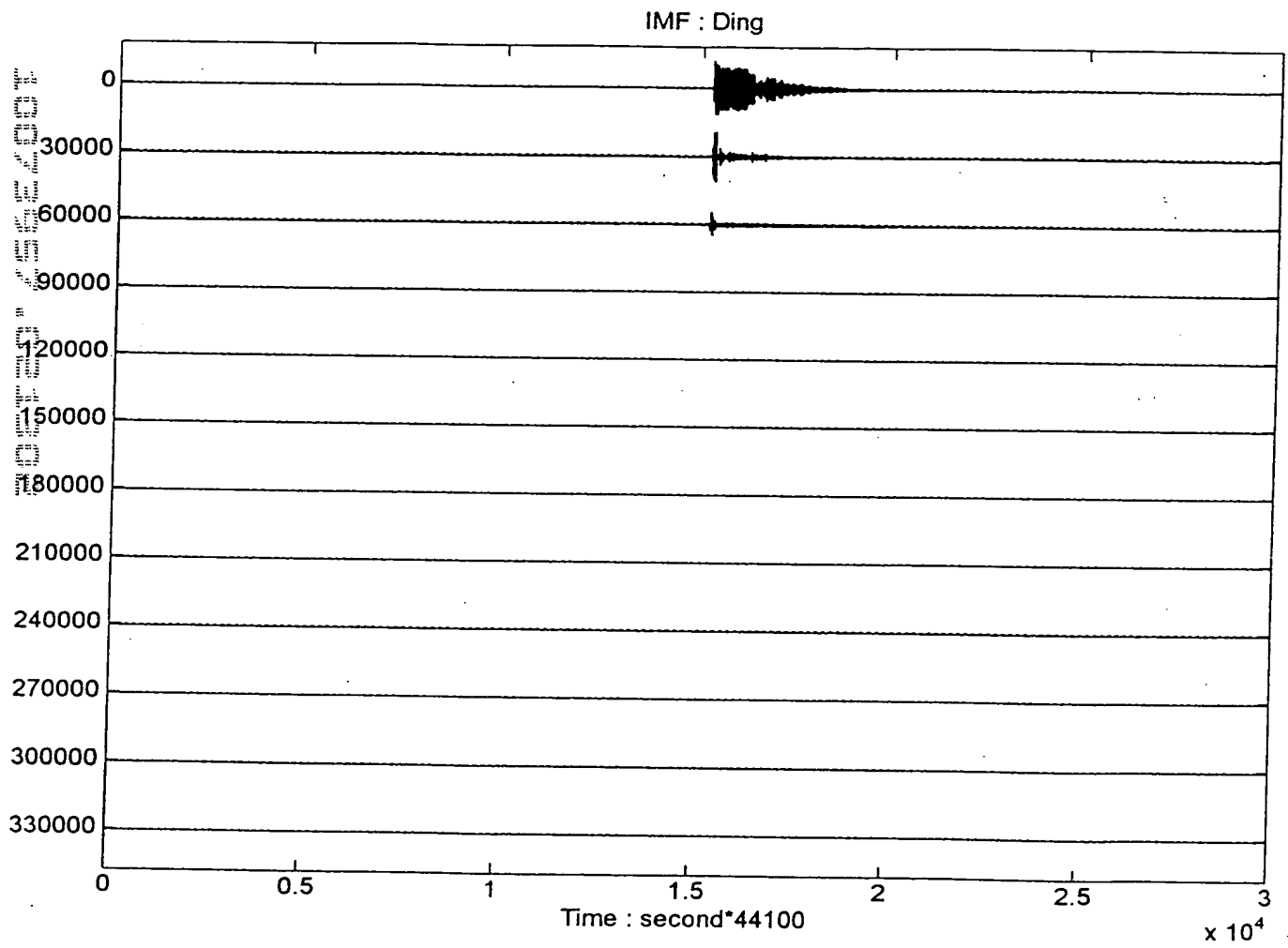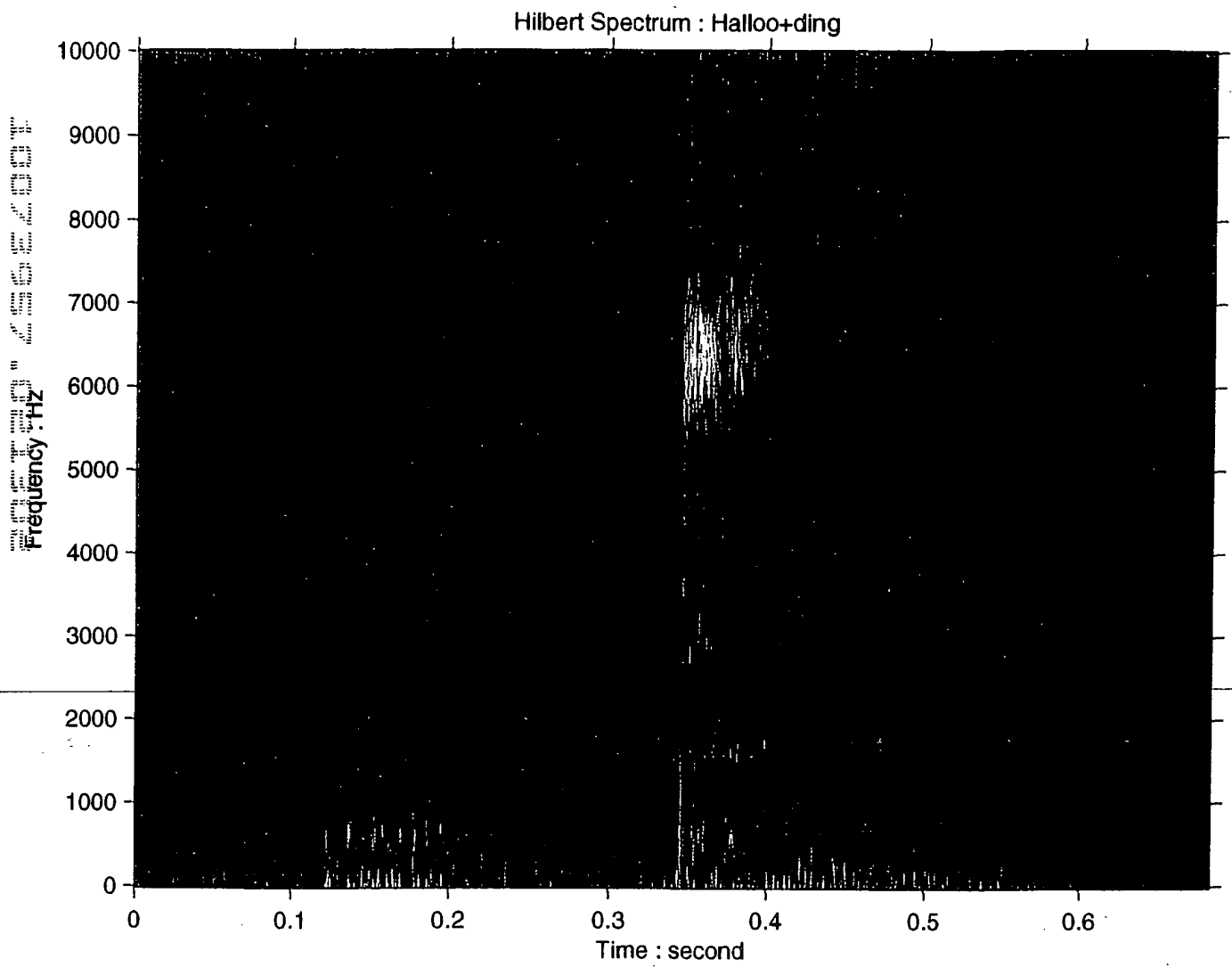
FIG. 57(b)

IMF : Ding

FIG. 58(a)

Hilbert Spectrum : Halloo+ding

FIG. 58(b)

Hilbert Spectrum : HHT filtered Halloo+ding

FIG. 59(a)

Data : HHT and Fourier filtered "Halloo+ding"

HHT Filtered

Fourier Filtered

Time : second

FIG. 59(b)

Fourier Spectra for the Halloo+Ding and Various Filtered Data

FIG. 60(a)

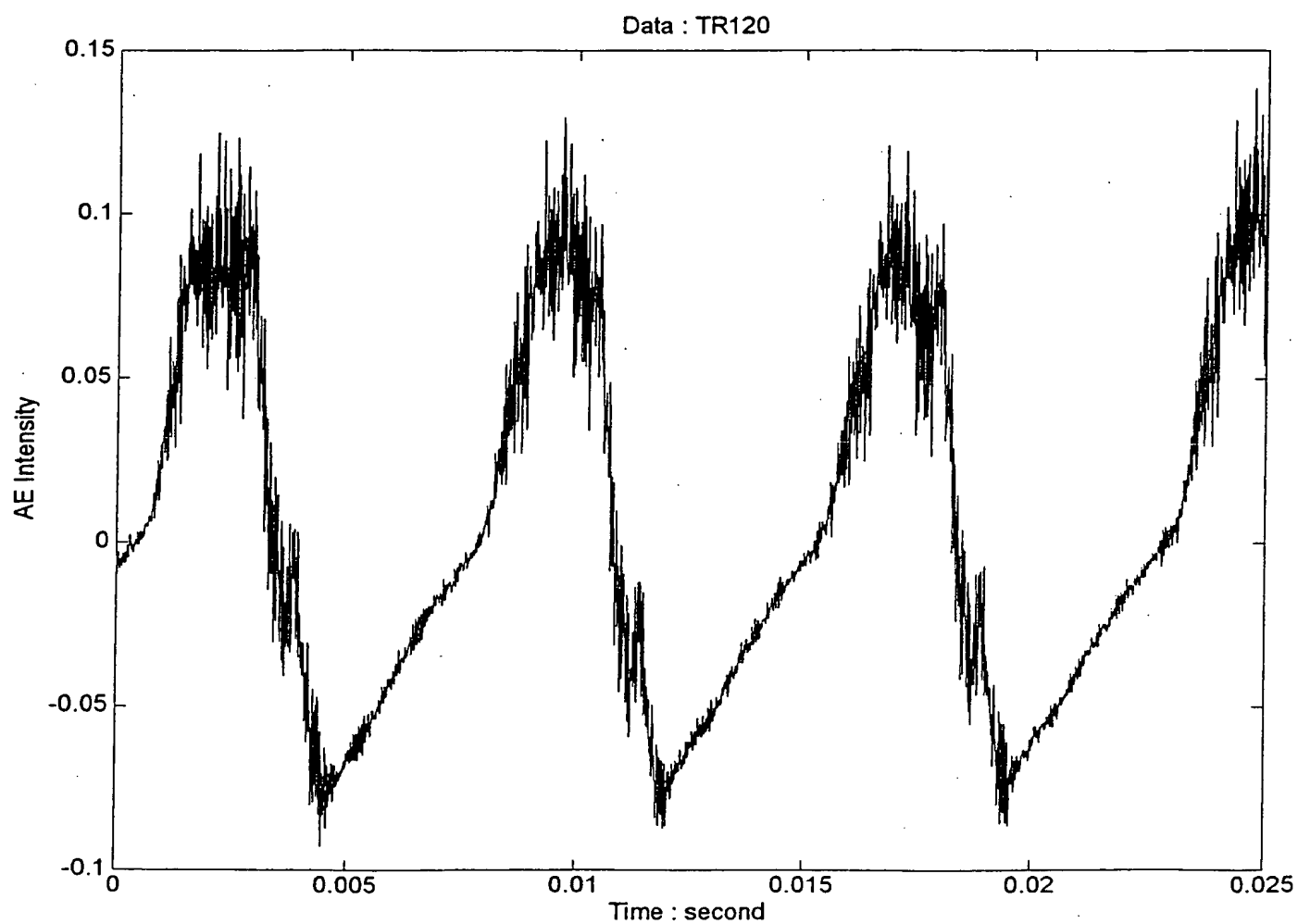FIG. 60(b)

FIG. 60(c)

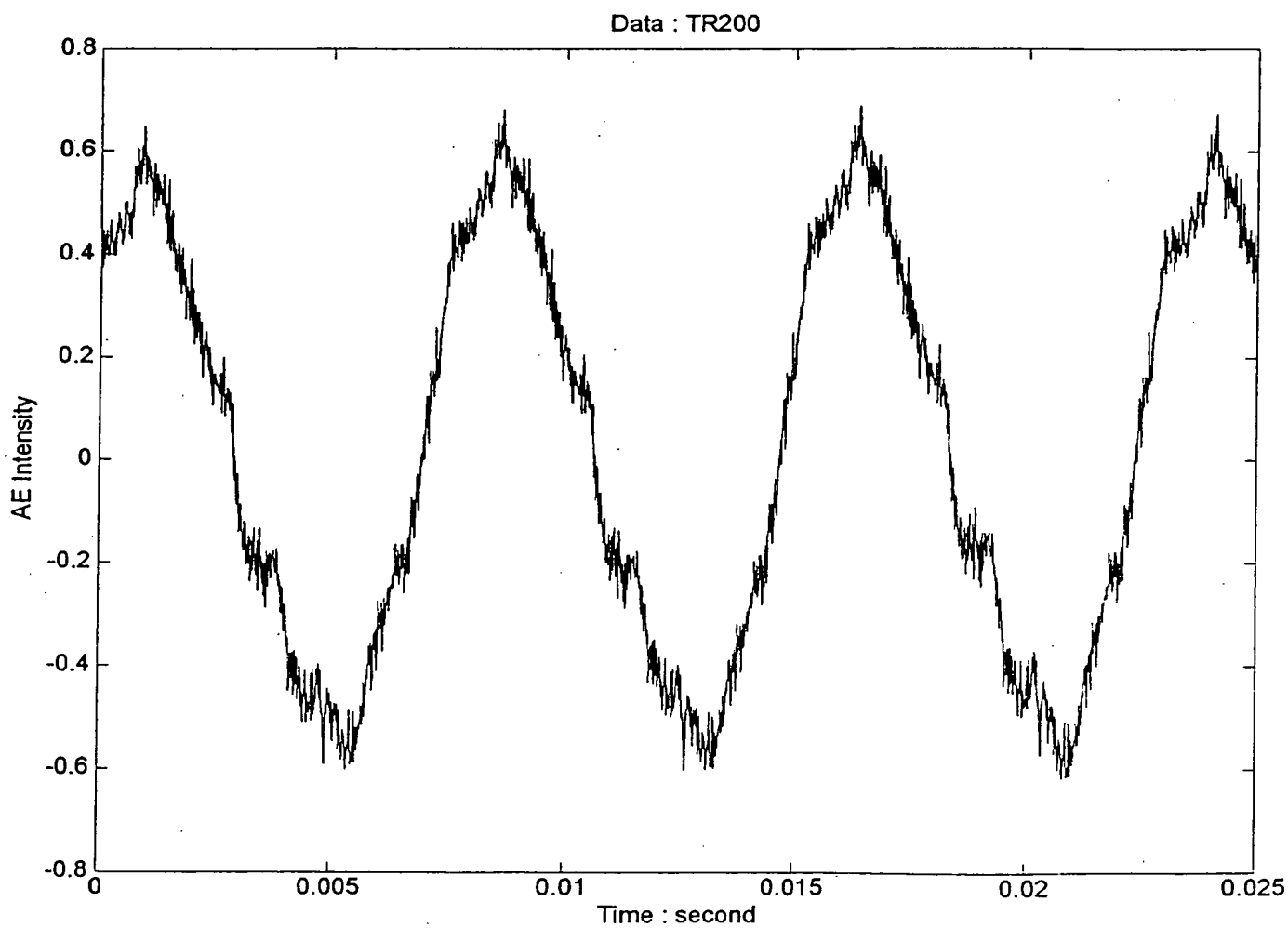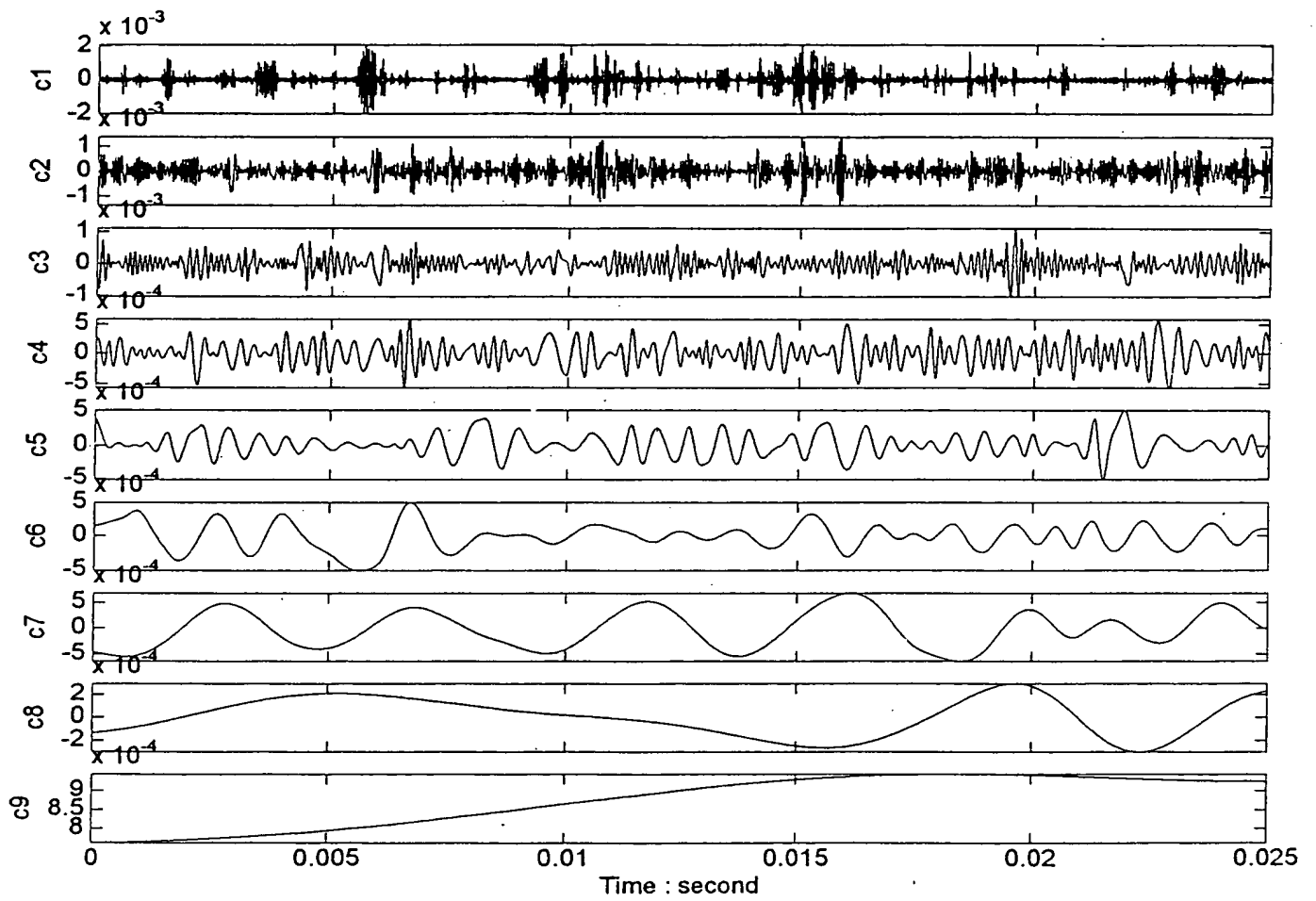Data : TR200

AE Intensity

Time : second
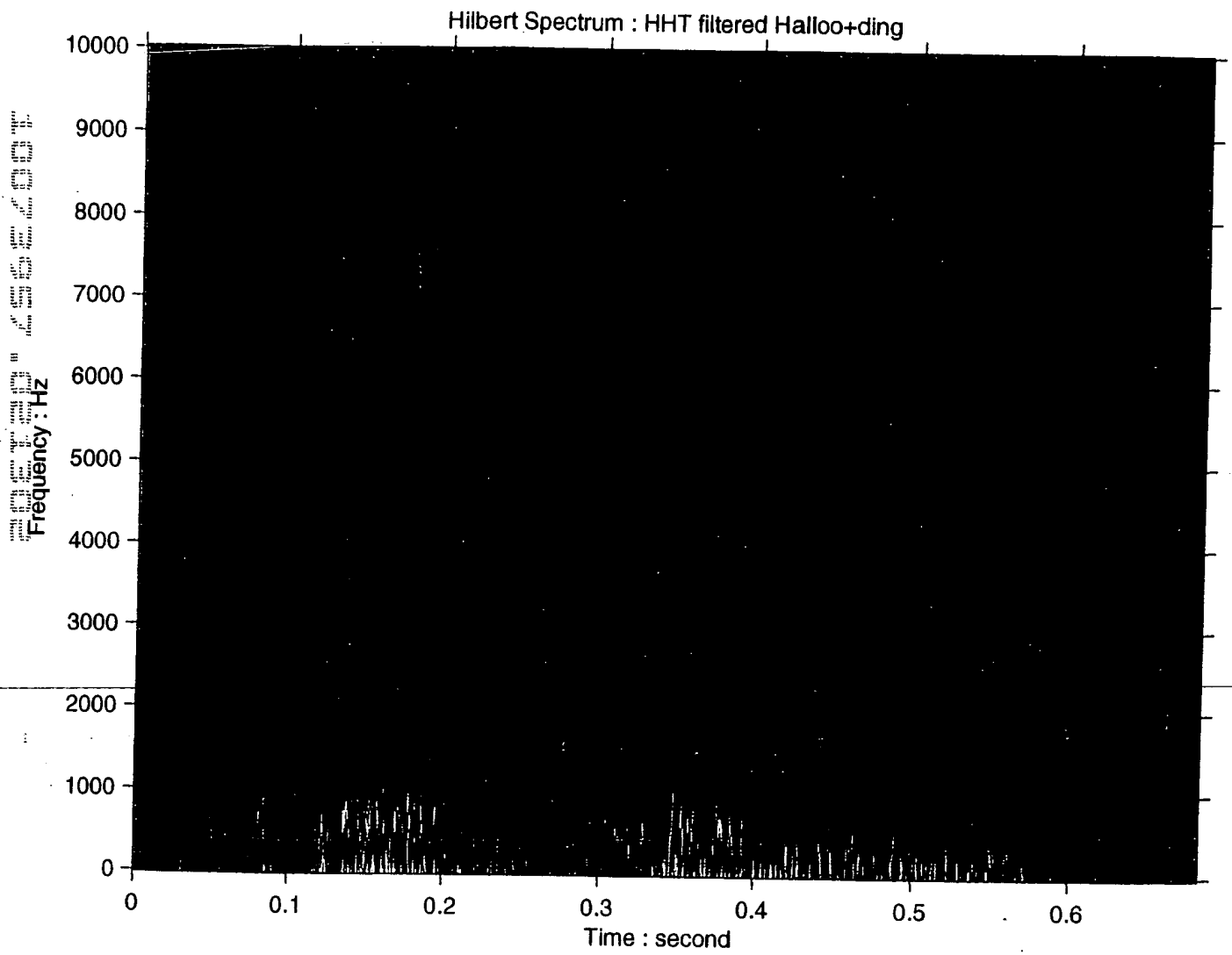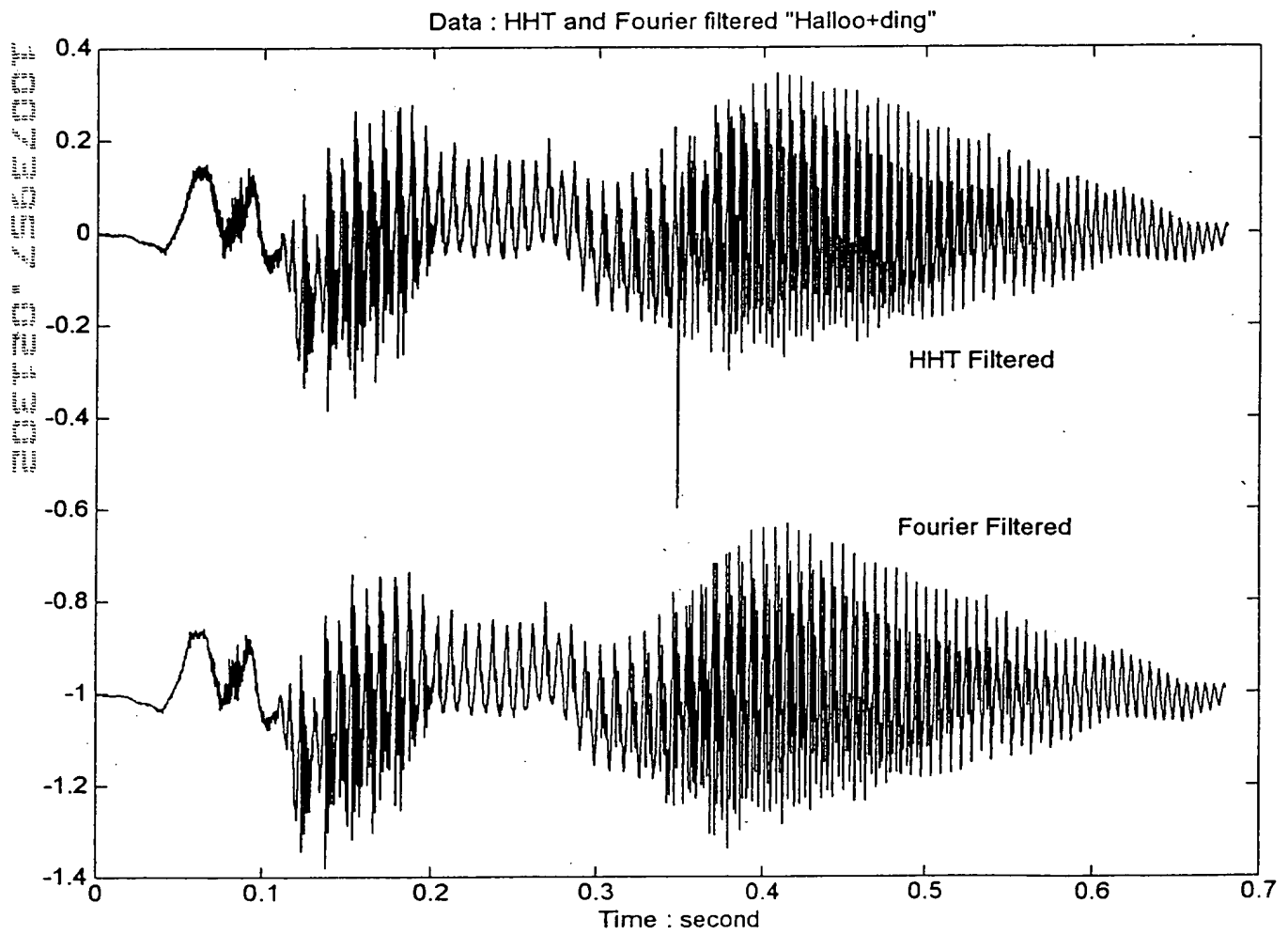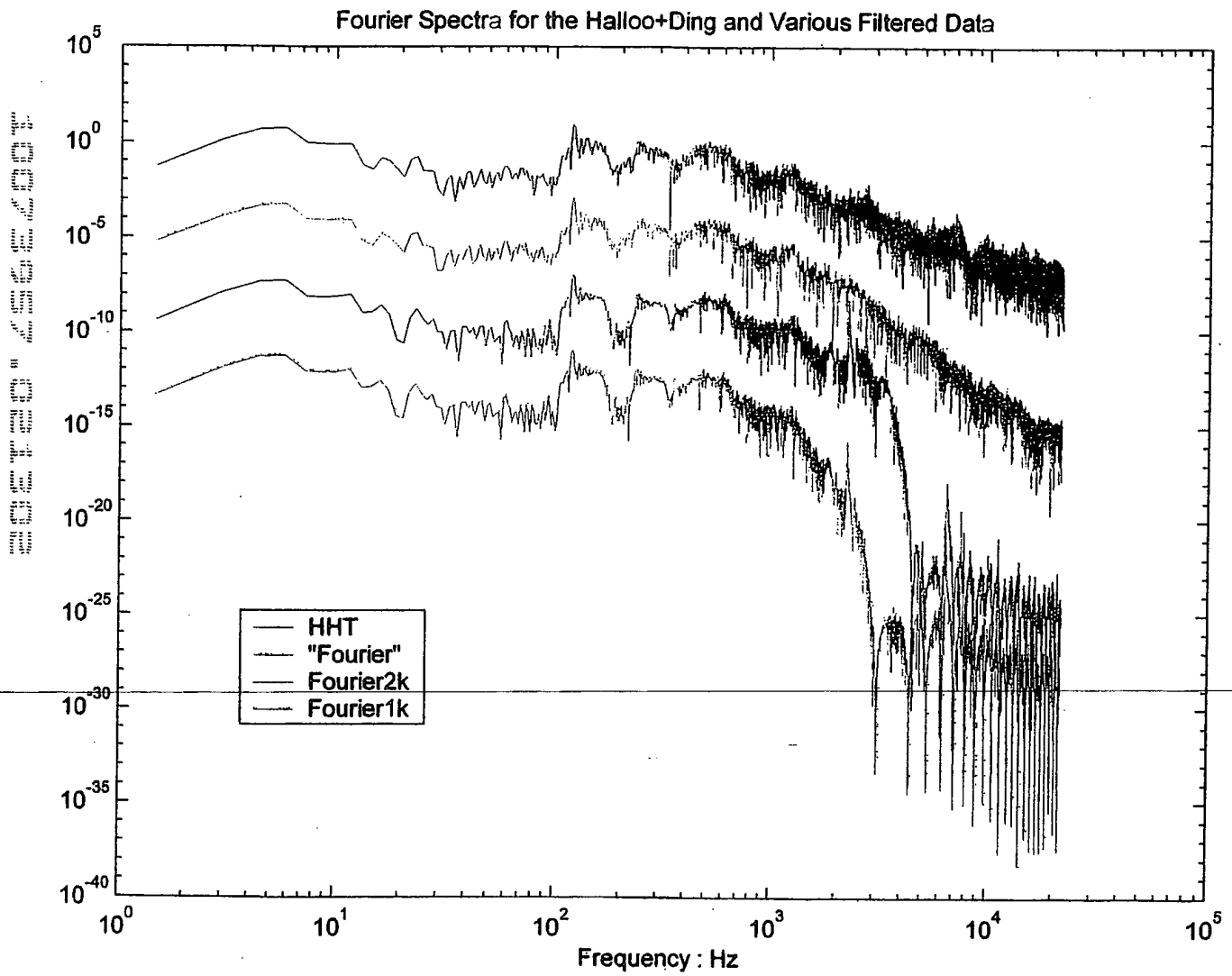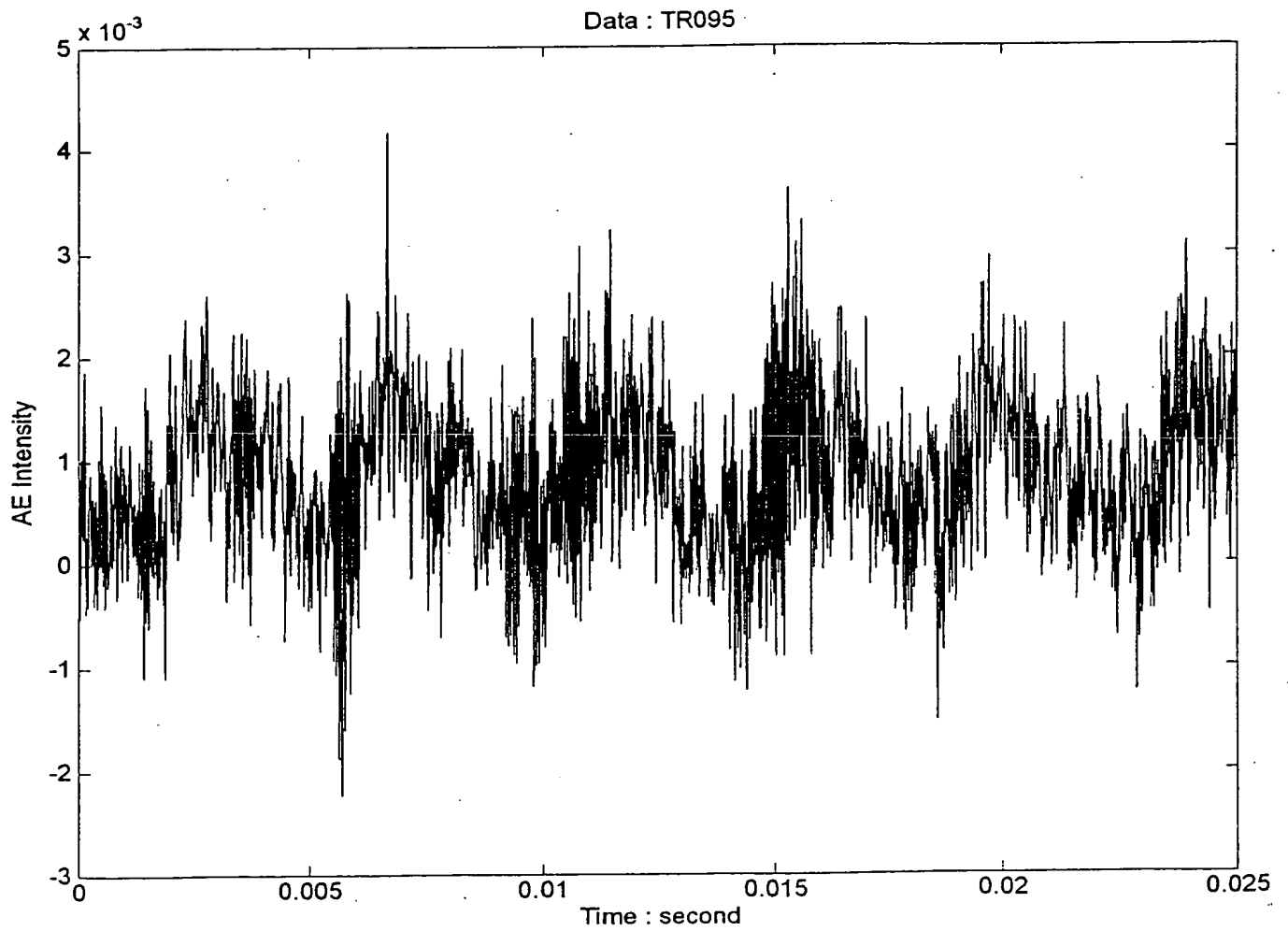
FIG. 61(a)
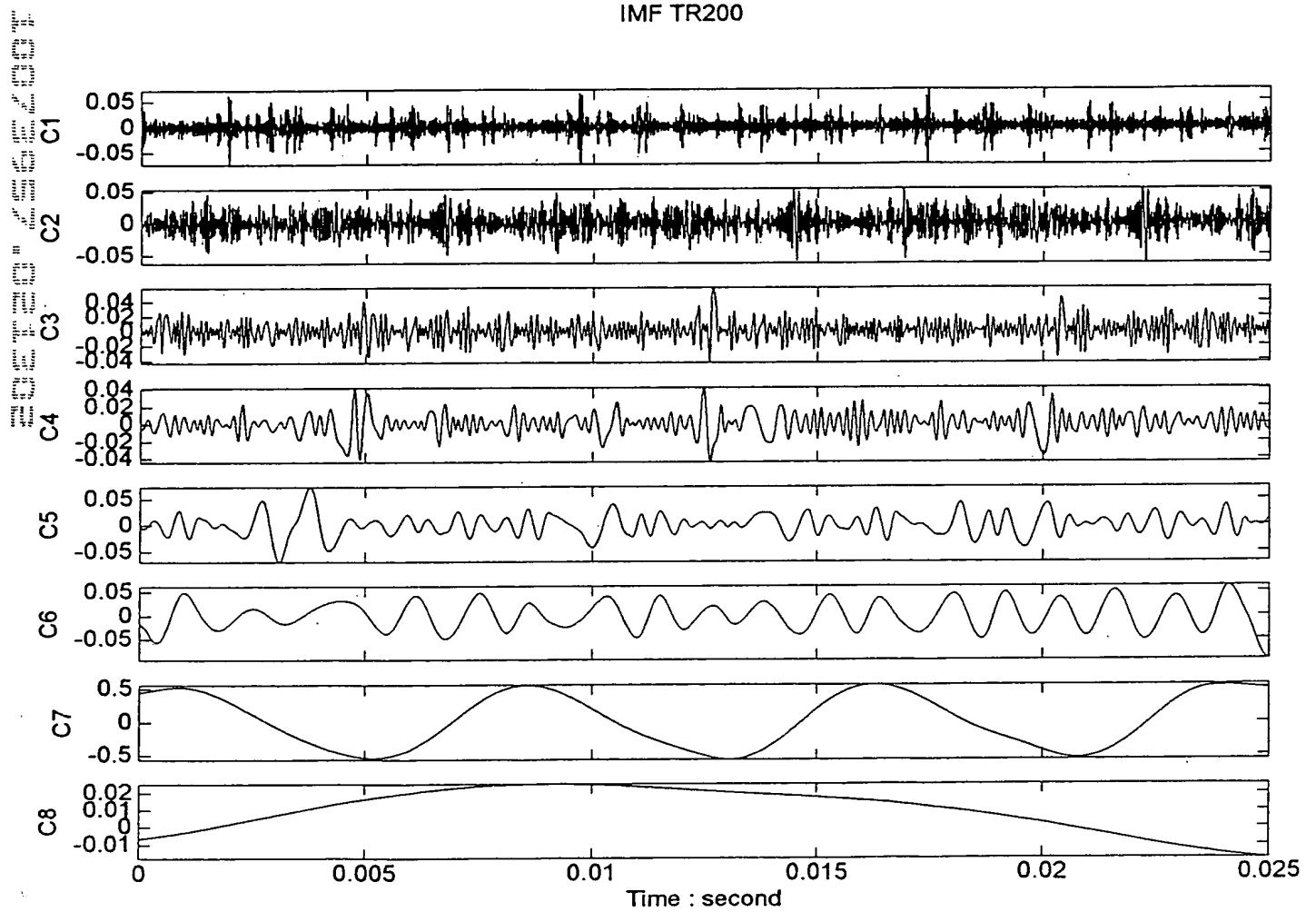
IMF TR095

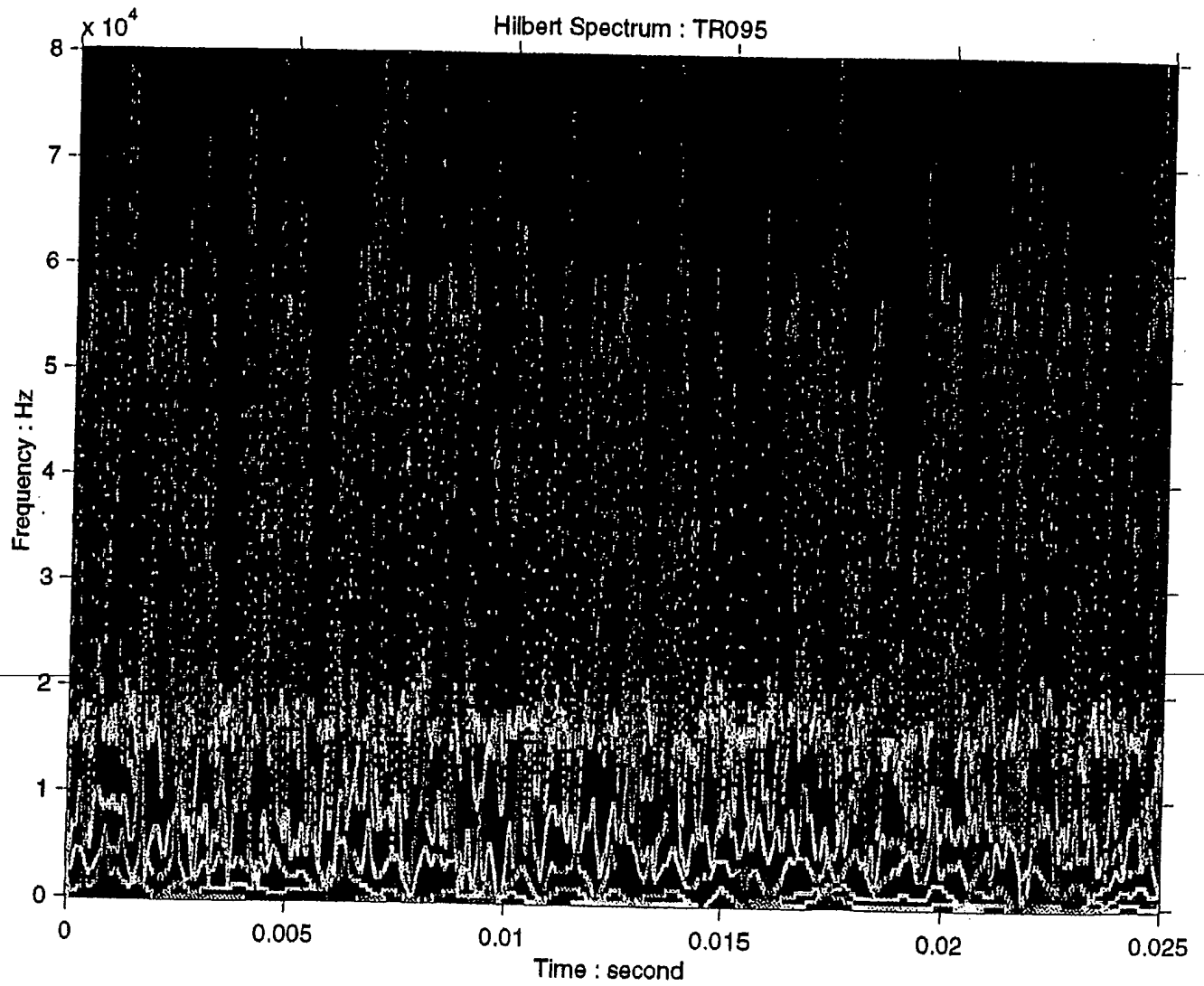# FIG. 61(b)

IMF TR120

FIG. 61(c)

IMF TR200

FIG. 62(a)

Hilbert Spectrum : TR095

FIG. 62(b)

Hilbert Spectrum : TR120

FIG. 62(c)

Hilbert Spectrum : TR200